MECHANICAL DRAWING

OUTLINE OF COURSE ENGINEERING 3*a*, HARVARD UNIVERSITY

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Special acknowledgment is due Professor G. C. ANTHONY, whose Text Book, "Mechanical Drawing," has suggested several of the exercises and problems given in these notes.

MEMORANDUM

General Directions

1. Directions in regard to the conduct of the course will be given at the lectures, and, when necessary, will be published in the Bulletin Board. Each student will be expected to note these directions, or, if absent from a lecture, to obtain them from some fellow-student. In any case he will be held responsible for all information given at the lectures or in the Bulletin Board.

Special Directions in Writing

2. Special directions given by any of the instructors in regard to the work of the course will be held valid only when accompanied by a written statement on the sheets, or on suitable blanks. Oral instructions cannot be verified, and will, therefore, be given no consideration.

Attendance

3. Credit for attending a meeting of the course is given on the understanding that a student has reported *at the office* at the beginning of the session, and has been in continuous attendance from that time until the final Roll Call.

Going out Early

4. Men who for any reason request to be excused early will be credited with partial time only in case their current work is up to date, and all previous work has been completed.

Signing Off

5. A student who has been signed off at the office can have his attendance record in this course corrected by bringing a memorandum suitably endorsed by the office. This memorandum should be presented *not later than one week* after the date of signing on.

Handing in Work

6. All work, to be accepted, must be handed in at the appointed times by the student personally, and not by proxy.

Overdue Work

7. A date set for overdue work will be considered final. No work presented after that date will be accepted, unless previous agreement in writing has been made.

Instruments and Materials

8. Each student is strongly advised to place an identifying mark on all his materials, including drawing instruments. All instruments and materials are left in the lockers during the year at the student's own risk, and *must* be removed from the lockers on or before the date set for the final examination. All articles not removed will be considered abandoned, and will be treated accordingly.

Tests

9. Tests will be held from time to time during the year. The results of these tests will have a very considerable weight in judging the work of the course. No make-ups will be given, but in special cases where a student is unable to be present at the time of a test, he may make arrangements to take it *in advance*. Unsatisfactory work in the tests *may* serve as a ground for failure in the course, without regard to the quality of the drafting work.

METHOD OF LAYING OUT DRAWING SHEET—USE OF MATERIALS

LECTURE DATE.....

METHOD OF LAYING OUT DRAWING SHEET — USE OF MATERIALS

DIRECTIONS

I. Fold and cut sheet into 4 equal parts.

The kind of paper used in this course is known as "**Duplex.**"

II. Thumb tack one part to Drawing Board. (One thumb tack in each corner.)

III. *Fig. 10.* With **T**-square laid across corners draw *short, light* lines **A B** and **C D**, thus finding approximate centre of sheet. (**Use 6 H Pencil.**)

IV. *Fig. 11.* With **T**-square draw **E F** (*light*) through centre. With *Triangle* draw **G H**. These are called "**Centre Lines**" of sheet.

V. *Fig. 12.* Along *Centre Lines* lay off **9** inches horizontally and **6** inches vertically, each side of centre. (Use *Triangular Scale* as shown.) With *T*-square and *Triangle* draw rectangle as shown. This is called the "**Cutting Line.**"

VI. *Fig. 13.* Again, lay off **8** *in.* and **5** *in.* on Centre Lines and complete second rectangle. This is called the "**Border Line.**"

VII. *Fig. 14.* The result is a sheet as shown; **18** *in.* by **12** *in.* (*outside measurement*) with **1** *inch* Border all round. This is called the "**Layout of Sheet.**"

NOTES

A. **Pencil.***

(*a*) **6 H** pencil sharpened, on *Sand Paper* pad, with *chisel* point. (*Fig. 1.*)

Used always for *Laying out Sheet* and *Blocking out Drawings.*

(*b*) **2 H** pencil sharpened, on pad, with *round* point. (*Fig. 2.*)

Used always for *Pointing Off Distances, Strengthening Outlines,* and *Lettering.*

(*c*) **Compass** pencil sharpened as in — (*Fig. 3.*)

Use **6 H** for Blocking out; **2 H** for Strengthening.

Use small *Needle Point* end in other leg of compasses. (*Fig. 4.*)

B. **Pen.**

(*a*) Have *both nibs* touching paper (*Fig. 5*), not (*Fig. 6.*)

(*b*) *Do not fill pen too full.*

(*c*) *Clean* pen often with pen-wiper.

C. **T-Square.**

(*a*) Always use *T-square* at *Left* end of board. (*Fig. 7.*)

If left-handed, change to Right end.

(*b*) Always draw along *upper* edge of *T*-square.

D. **Triangles.**

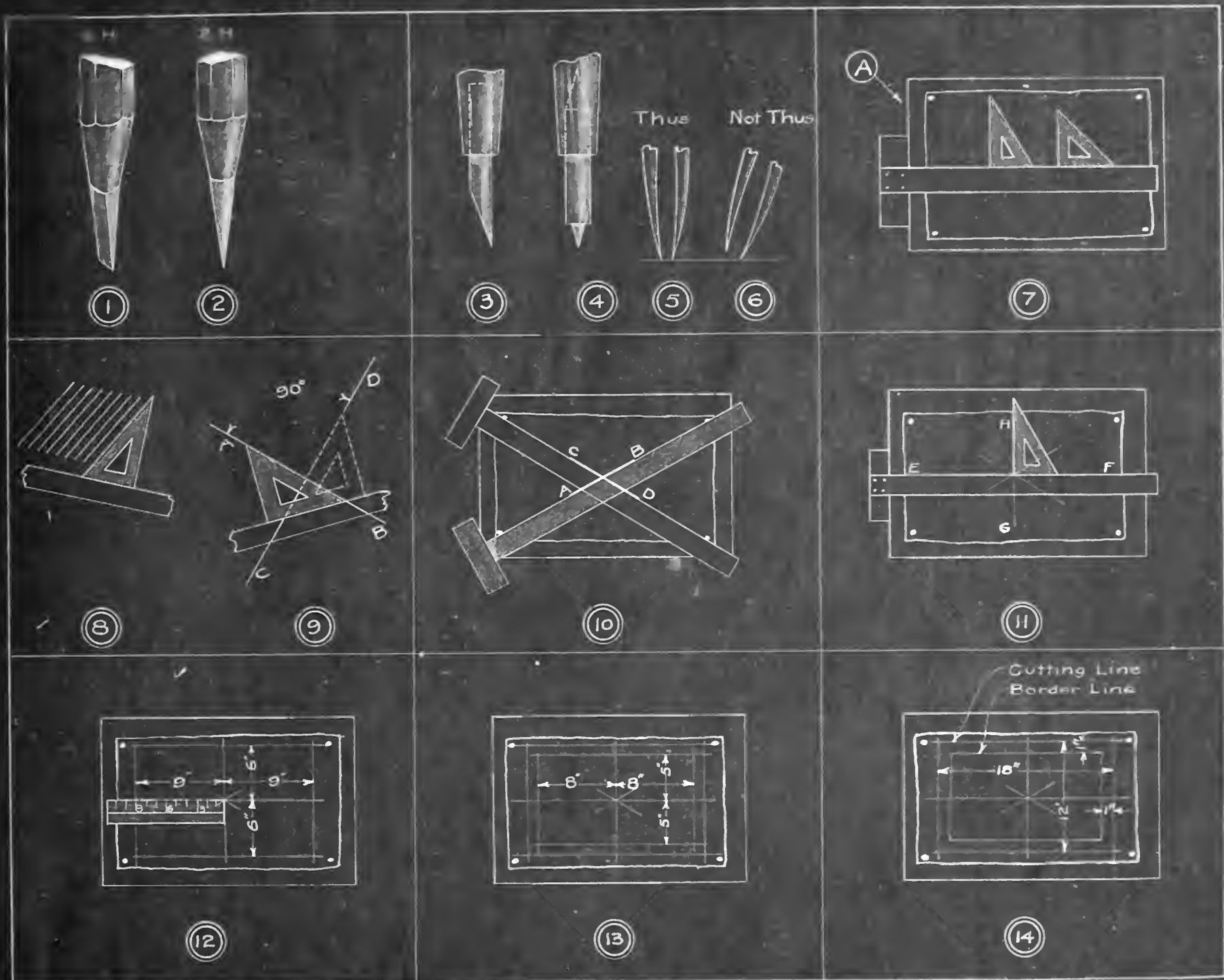
(*a*) Always use *triangles* on *top edge* of *T*-square.

Wherever possible draw with light coming from Direction (**A**). (*Fig. 7.*)

(*b*) To draw *Parallel* lines, slide triangle along Straight Edge (either *T*-square or another triangle). (*Fig. 8.*)

(*c*) To draw *Perpendicular* to a given line, place triangle against a Straight Edge, as shown in *full lines;* then turn triangle to *dotted* position, slide along to required point and draw perpendicular **C D.** (*Fig. 9.*)

* Whenever possible draw lines from **Left** to **Right** and from **Bottom** towards **Top** of sheet.


S H
2 H
Thus
Not Thus
A
1
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3
4
5
6
7
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90°
D
C
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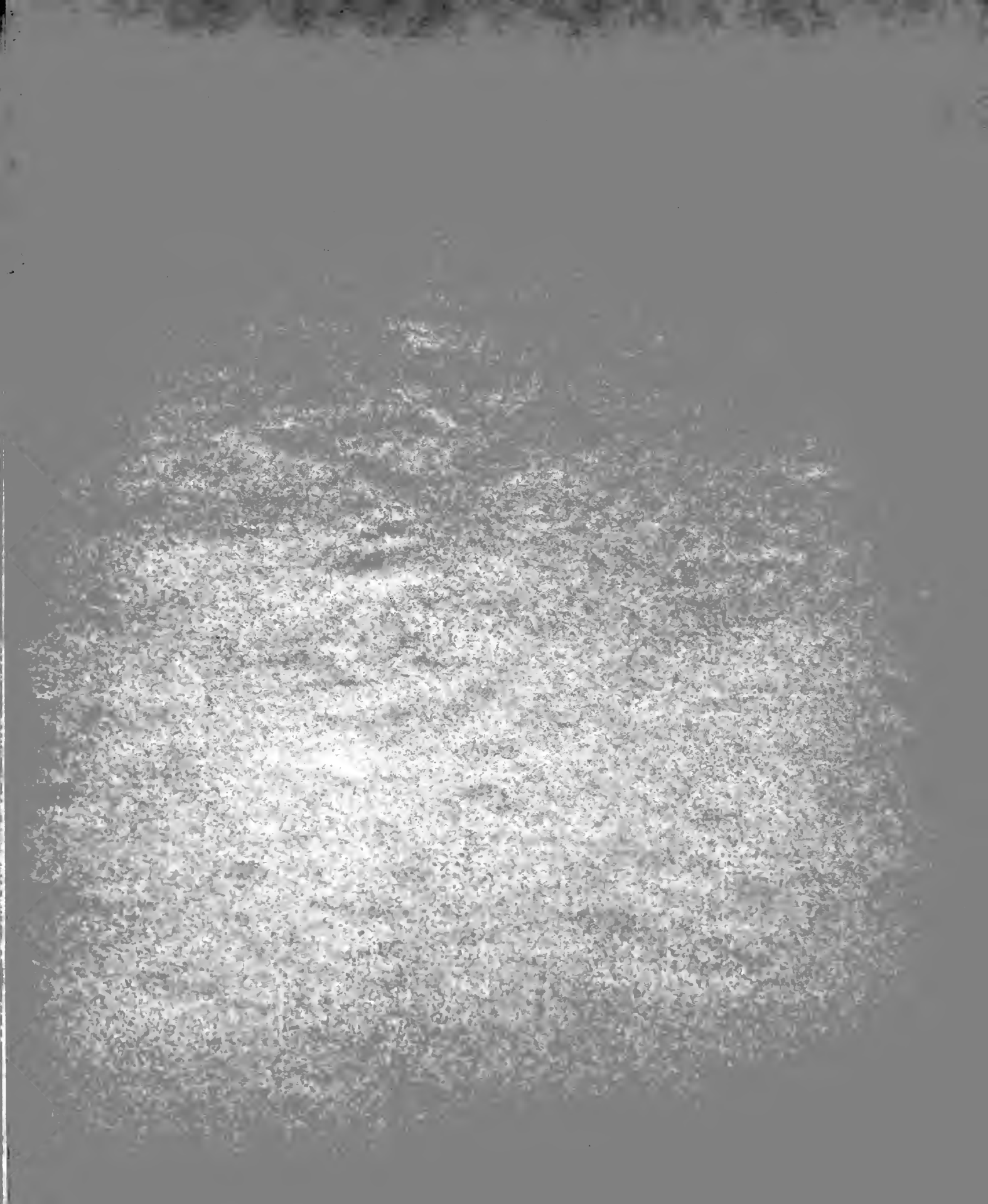
9
10
H
E
F
G
11
9"
6"
12
8"
5"
13
Cutting Line
Border Line
18"
N
14



LECTURE DATE .....

DIRECTIONS

I. Lay out sheet as explained. (Page 6.)

II. Place your number (in *black* ink) in the upper right hand margin of sheet.

III. Draw all *guide lines* for letters, *very light*, spaced as shown, and with **6 H** pencil. (Sharpened as shown by Page 6–A–a.)

IV. (*a*) Copy *freehand* the letters and figures indicated. Consult Page 111 for construction of letters.

(*b*) Use **2 H** pencil. (Sharpened as shown by Page 6–A–b.)

(*c*) Press lightly.

(*d*) Make all letters *Vertical* as in copy.

(*e*) Make letters *round* and *full*.

(*f*) *Do not crowd.*

V. Add Title.

(*a*) Draw base line for title $\frac{1}{2}$ *inch* below *Border Line.*

(*b*) Begin title far enough to the left to end exactly under (**A**).

(*c*) To do this, determine length of title by blocking it out on another paper, or on margin outside of cutting line.

NOTES

A. All statements enclosed in *Rectangles* are to be omitted from the drawing sheets.

They are for direction only.

B. The numerical dimensions given on the blue prints may not always agree with the "scale" (proportion) or with the exact arrangement shown. In such cases follow the *dimensions*. This is the general rule in reading working drawings.

C. The lettering used in this course is an adaptation of the "*Reinhardt*" * **Gothic Alphabet.** Make the *small* letters $\frac{1}{8}$ *inch* high; the *capitals* and *figures* $\frac{3}{16}$ *inch* high.

This size will be called "**Standard,**" and will be used for general lettering throughout the course.

In *fractions* make numerator and denominator figures each about $\frac{2}{3}$ standard size.

D. The location and arrangement of title on Sheet 1 will be called the "**Standard Title,**" and will be used on all sheets of this size.

* See "*Lettering*" by Chas. W. Reinhardt.

Cutting Line

Border Line

No.

AAA BBB — On this line make 3 of each letter from A to G inclusive.

HHH III — H to Q

RRR SSS — R to Z

111 222 — Figures 1 to 10

$\frac{1}{16}$ $\frac{2}{16}$ $\frac{3}{16}$ — Fractions, varying by $\frac{1}{16}$, up to 2

aaa bbb — Small letters a to g

hhh iii — h to q

rrr sss — r to z

Leave remaining lines for text to be given out later by instructor

A

Eng'g 3a - Sheet I - John Harvard 147

For Construction of Letters see page 111.

LECTURE DATE.....

SHEET 2 — PRACTICE IN PENCIL LINES

DIRECTIONS

I. *Upper Left.* Horizontal Lines.

(*a*) Space off with scale along *Vertical Centre Line* of sheet.

(*b*) Begin at *Top* and work down. (Use *T*-square.)

II. *Upper Right.* Vertical Lines.

(*a*) Space off along *Horizontal Centre Line.*

(*b*) Begin at *Left* and work to *Right.* (Use *T*-square and *Triangle.*

III. *Lower Left.* Slanting Lines.

(*a*) Use *T*-square and *45° Triangle.*

IV. *Lower Right.* **Parallel Lines.**

(*a*) Draw Parallelogram **A B C D.**

(*b*) *Outside* draw lines parallel to **A B.**

(*c*) *Inside* " " " " **B C.**

(Use Method given on Page *6–D–b.*)

V. Add *Title* and *Number* as in Sheet *1.*

NOTES

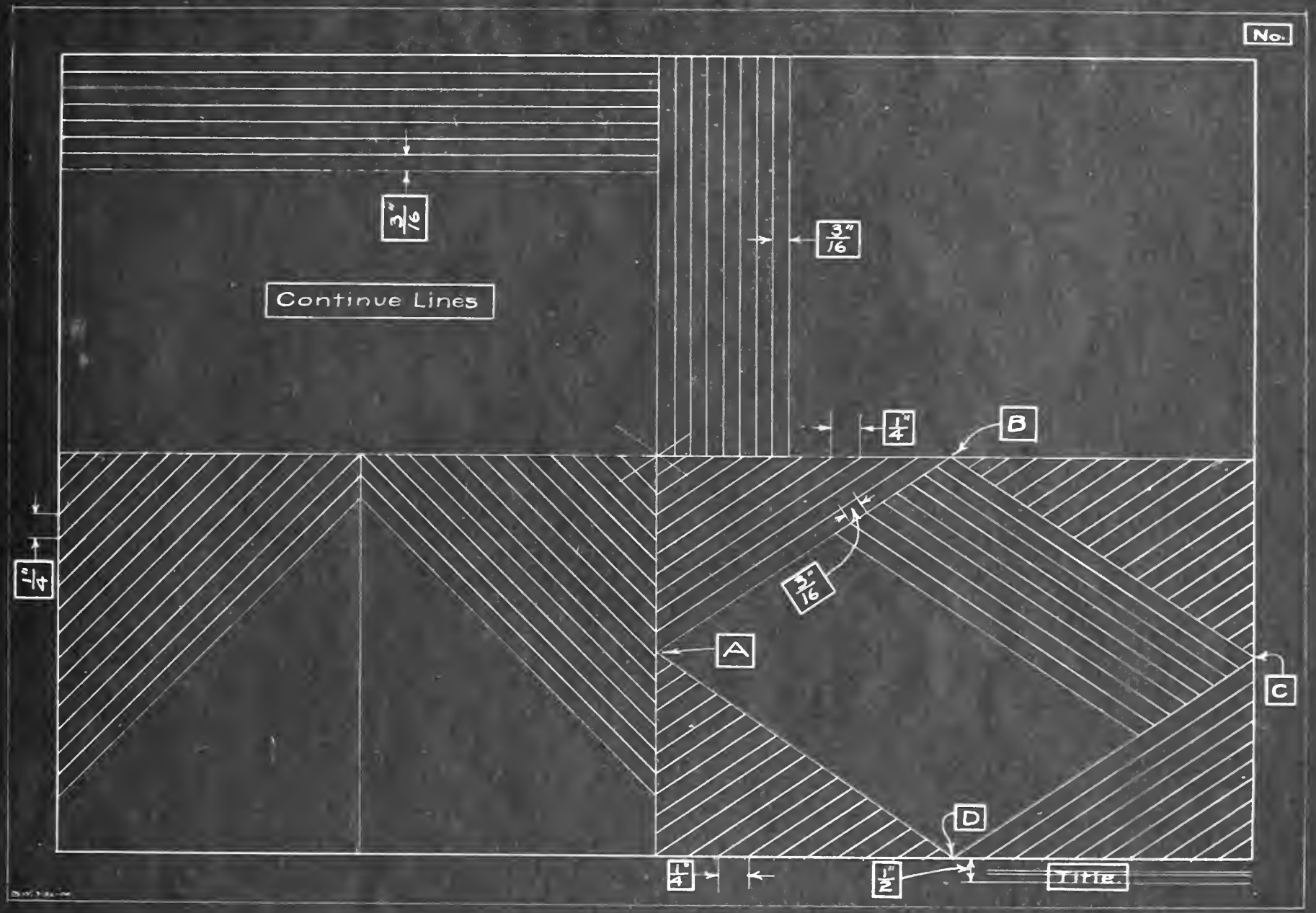
A. Lines to be: —

(*a*) **Fine.**

(*b*) **Uniform.**

(*c*) **Accurately drawn.**

(Use **6 H** peneil, sharpened as shown by Page *6–A–a.*)



Sheet 2.

LECTURE DATE.....

DIRECTIONS

I. *Ex. 1.* Given 2 Circles, *3 inch* diam. and *4 inch* diam., respectively.

Circumscribe Hexagons.

The larger with two sides horizontal, the smaller with two sides vertical.

Use *T*-square and *60°* Triangle *only*.

II. *Ex. 2.* Given Circle 3½ *in.* diam.

(*a*) Draw lines *15°* apart as shown. Use *T*-square, **45°** and **60°** Triangles *only*.

(*b*) On left half of Circle draw *Tangent* at end of *every other line* by method of 2 Triangles. See Page *6–D–c*.

(*c*) On right half of Circle draw *Tangents* at end of *any 3* lines by geometry.

See note at bottom of Sheet *3*.

III. *Ex. 3.* Given Circle 3½ *in.* diam. Lay off angles as shown. (Use *Protractor*.)

Do not add arrows or figures.

IV. *Ex. 4.* Given Line at angle of 37½° with Horizontal. (Use *Protractor*.)

On this line as base draw a regular *Hexagon*, each side = 1½ *inch*. (Use any accurate method that suggests itself.)

V. *Ex. 5.* Given Circle 3¼ *in.* diam. Inscribe a regular *Pentagon*. (For other polygons, see Page *113*.)

VI. *Ex. 6.* Given Circle *4 in.* diam. Inscribe small circles as shown.

Use *Bow Pencil* on smaller circles.

NOTES

A. *Lines* and *Circles* to be: —

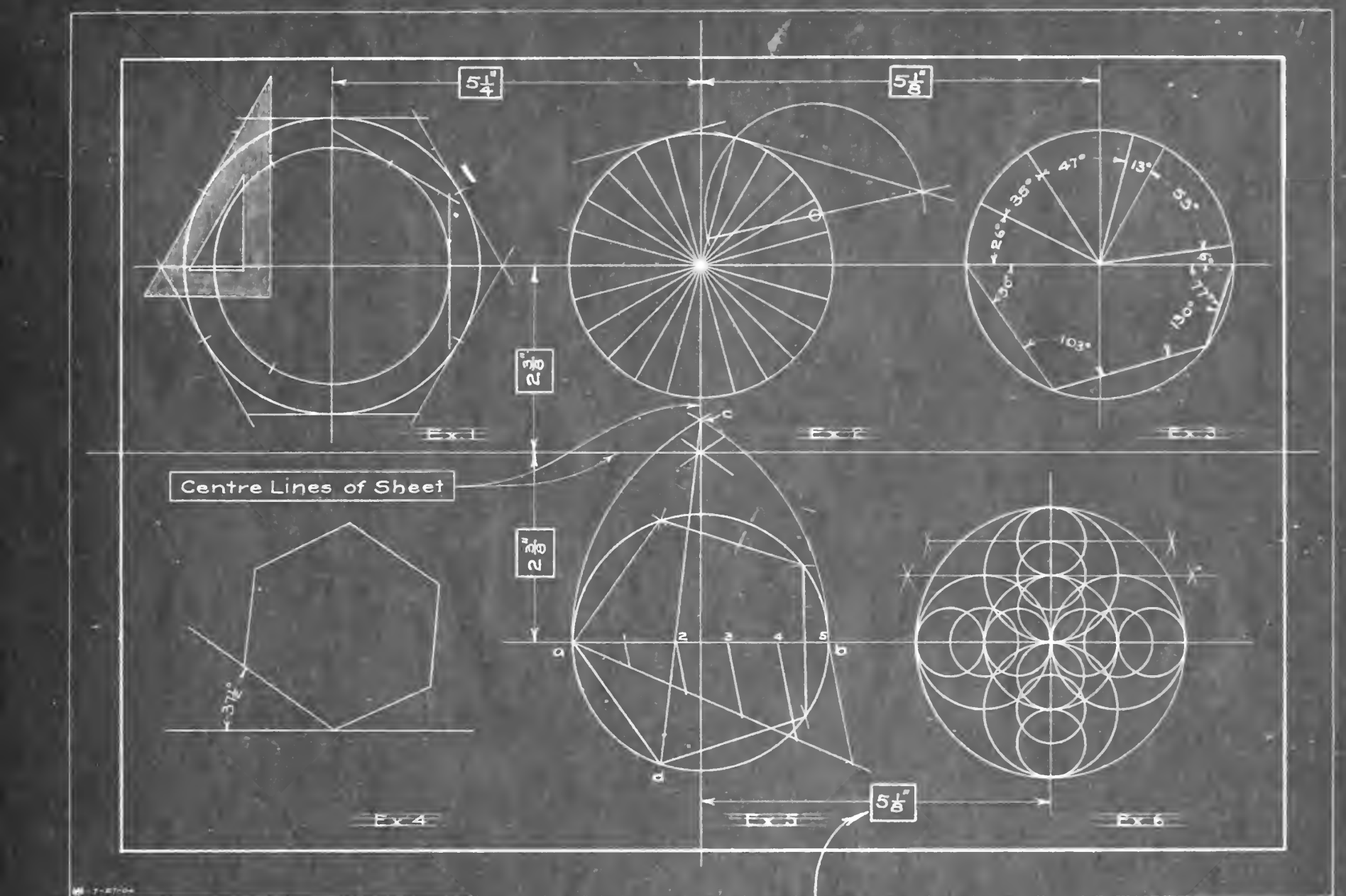
(*a*) *Fine.*

(*b*) *Uniform.*

(*c*) *Accurately drawn.*

Use *6 H* Pencil and *6 H* lead in Compasses.

(Sharpened as shown by Page *6–A–c*.)



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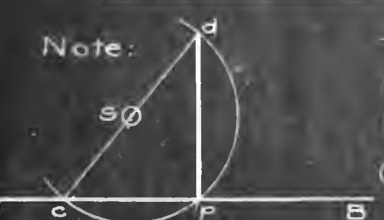


To erect a perpendicular to AB at p.
Draw circle thro' p. center s = any point.
Draw cd thro' s. pd = perpendicular.
(Angle cpd inscribed in semi-circle = 90°)

Follow dimensions rather than scale
See note B on page 10

LECTURE DATE.....

PENCILLING

I. Lines to be: (*a*) *FINE.*
(*b*) *UNIFORM.*
(*c*) *ACCURATE.*

LAY OUT SHEET AS SHOWN.

II. *Ex. 1.* Space lines $\frac{1}{4}$ *in.* apart.

III. *Ex. 2.* Space points $\frac{1}{4}$ *in.* horizontally and vertically. (Lines at 45°.)

IV. *Ex. 3.* Space lines $\frac{1}{4}$ *in.* apart.

First draw diagonal; then draw lines in order, **A**, **B**, **C**, **D**, etc.

V. *Ex. 4.* Space points $\frac{1}{2}$ *in.* apart.

VI. *Ex. 5.* **Spiral.**

(*a*) Make **a c** = $\frac{1}{4}$ *in.*; **a b** = $\frac{1}{8}$ *in.*

(*b*) With **a** as centre, draw all semicircles *above* horizontal line. With **b** as centre, all semicircles *below*.

Use **a** and **b** alternately to develop *Spiral*. Continue as far as possible without conflict.

VII. *Ex. 6.* **Tangent Arcs.**

(*a*) Outside circle of rim *4 in.* diam.; inside, $3\frac{1}{2}$ *in.* Spokes $\frac{3}{4}$ *in.* wide, centre lines 120° apart. Radius of tangent arcs $\frac{5}{16}$ *in.*

(*b*) Locate centres for arcs thus:

Draw circle **A** $\frac{5}{16}$ *in.* inside of rim.
Draw line **B** $\frac{5}{16}$ *in.* from spoke.
Intersection gives centre of arc.

VIII. *Ex. 7.* Space points $\frac{1}{4}$ in. apart on horizontal line. Complete figure as shown.

Use *Bow Pencil* for small circles.
Draw all curves of one radius at one time.

INKING

A. (*a*) Sheet is to be completed first in *pencil*.

(*b*) *Do not begin to ink until sheet has been submitted for approval, and has received endorsement of one of the instructors.*

B. (*a*) Do not fill pen too full. (See PAGE *6–B.*)

(*b*) Clean pen often.

C. (*a*) All lines to be **Black** and of **Medium Width,** *except* **Border,** which is to be **Heavy** and added *last.* (See note on blue print.)

(*b*) In inking, proceed in same manner as with pencil.

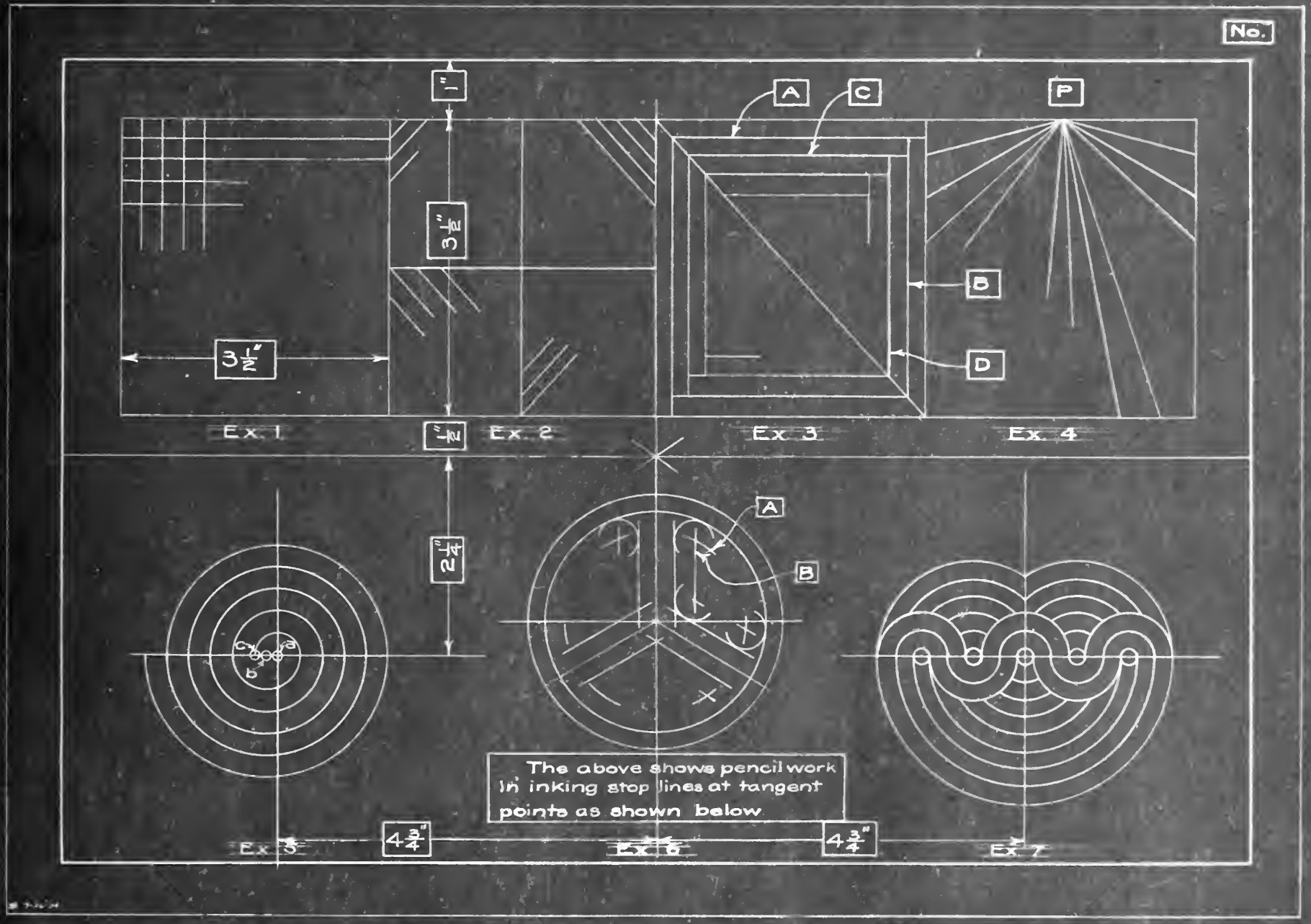
Begin at *Left* and work towards *Right*, and from *Top* work towards *Bottom*.

(*c*) In **Ex. 4** draw lines *to* point **P,** *not away* from it.

(*d*) In *Ex. 5, 6, and 7,* omit construction and Centre Lines.

(*e*) In Lettering use drawing ink and writing pen.

(*f*) *Do not ink Cutting Line.*



NOTE: In Inking make.

Medium Lines about thus: ———

Heavy Lines about thus: ———

Ex. 8

Sheet 4.

SHEET 5

PRACTICE IN STRAIGHT LINES AND ARCS, DIMENSIONING AND CROSSHATCHING, TRACING

LECTURE DATE.....

DIRECTIONS

I. **Order of Pencilling*** (See PAGE *28–1*.)

Stage 1. Block out all drawings on sheet. (**6 H** pencil.)
First *Centre Lines*, if any, then *Outlines*.

Stage 2. Develop drawings and **Strengthen** Outlines. (**2 H** pencil.)
Connect straight lines by arcs. (See PAGE *28–3*.)

Stage 3. Draw **Dimension Lines** (*very light*) and **Arrow Heads.** (**2 H** pencil.)

Stage 4. Finish.
(*a*) *Dimension Figures.* (PAGE *28–4* and *5*.)
(*b*) *Lettering.*
(*c*) *Crosshatching.*‡
(*d*) *Checking.* (Use red pencil.)

II. The pencil sheet should be shown to one of the instructors before tracing is begun.

III. **Order of Inking.**

Use *rough side* of tracing cloth.
Rub with *powdered chalk* before inking.

Stage 1. All the *main outlines* of all the drawings.
(*a*) *First* all **Curves.**†
(*b*) *Then* all **Straight Lines.** (BLACK MEDIUM.)

Stage 2. Dimension Lines (including "*Extension*" *Lines*) and **Centre Lines** (if any). (RED-LIGHT.)

Stage 3. Arrow Heads, Figures, and **Lettering.** (Use *Writing Pen.*) (BLACK.)
Draw light guide lines on tracing cloth in pencil before lettering.

Stage 4. (*a*) **Crosshatching.** (BLACK-LIGHT.)
(*b*) **Border.** (BLACK-HEAVY.)
(*c*) **Checking.**

* Page *29* is to be used at first only to give dimensions and later to show what is to appear on the tracing. Carry out pencil construction as shown by PAGE *28*.

† This procedure gives best results in *joining Curves* and *Straight Lines* smoothly.
The short curves shown on this sheet are often called "**Fillets.**"

‡ When a drawing is to be traced the Crosshatching is often omitted in pencil, or is indicated very briefly by Free Hand lines.

NOTES

A. In both Pencilling and Inking it is best to carry out each Stage for the *whole* sheet before beginning the next Stage.

B. **Accurate Construction** is required.
Method of connecting "tangent" arcs, as shown by PAGE *28–3* should be studied. (See also PAGE *113*.)

C. **Dimensions are Important.**
(*a*) For dimensions in *Quarters*, *Eighths*, *Sixteenths*, etc., use "**Architect's**" Scale.
For dimensions in Decimals use "**Engineer's**" Scale.
(*b*) Avoid taking dimensions with Compasses directly from Scale.
This scratches scale and ruins compass points. Lay off distance on paper at required point and set compasses to this distance.
(*c*) Dimension figures are preferably made standard size. Best, at first, to draw guide lines for them as for lettering.
(*d*) *Small Circles* are placed around centres of arcs to assist in finding them when tracing. On the tracing, short cross lines (+) are sometimes used to denote centres.

D. **Crosshatching.**‡
(*a*) *Crosshatching* is used to indicate a "**Cross Section**" of an object drawn.
(*b*) It is usually drawn with the **45°** *Triangle*.
Other angles may, however, be used.
(*c*) Space lines about $\frac{1}{16}$ in. apart by *EYE ALONE*.
(*d*) Do not cross Figures or Arrows with hatching lines.
(*To avoid this the Crosshatching is usually added last.*)

E. **Checking.**
(*a*) Apply *four tests* to every dimension.
1. Are the dimension figures correct? (Consult blue print.)
2. Does "scale" agree with dimension figure? (Measure distance as drawn.)
3. Are "unit marks" shown? (See *4–a* on PAGE *28*.)
4. Are arrow heads and "extension lines" shown? (See *5* on PAGE *28*.)
(*b*) All statements and specifications should also be verified.
(*c*) Place small check mark neatly *above* each item found correct. (See PAGE *29*.)
If error is found, correct it before checking.

ORDER OF PENCILLING
4 Stages

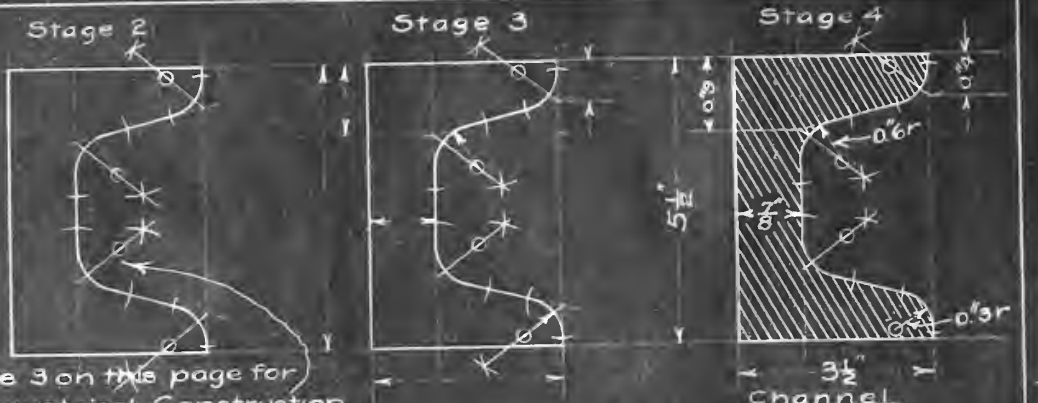
(1)

Stage 1 — "Blocking Out"

Stage 2 — "Developing"

Stage 3 — "Dimension Lines"

Stage 4 — "Finish."



See 3 on this page for Geometrical Construction

ORDER OF INKING
4 Stages

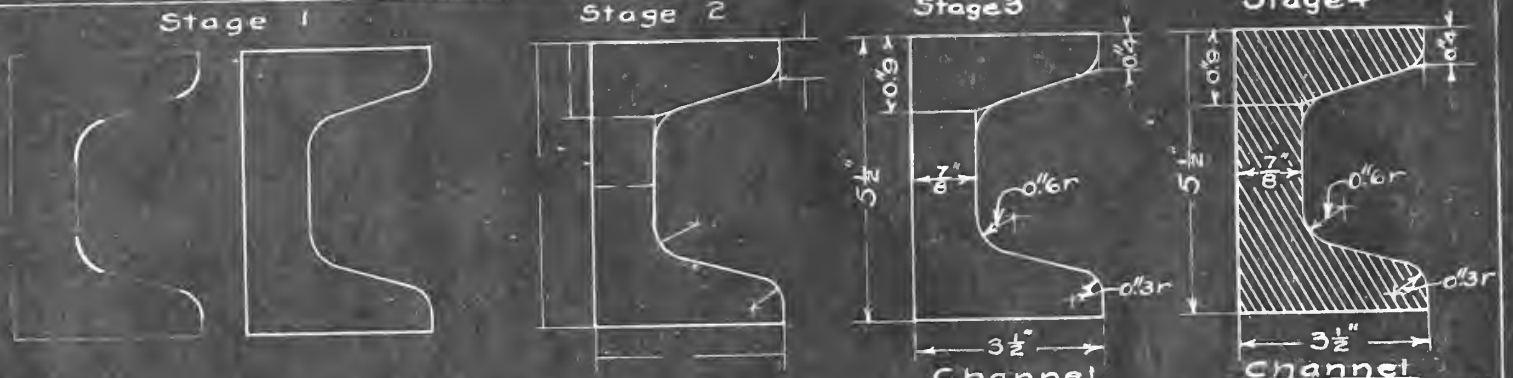
(2)

Stage 1 — (a) "Curves" (b) "Straight Lines"

Stage 2 — "Dimen. Lines"

Stage 3 — "Arrows, Figures, etc"

Stage 4 — "Cross hatching"



(3)

TO CONNECT 2 STRAIGHT LINES BY AN ARC

(1) Bisect angle

(2) Draw cd parallel to ab- (making bc equal to given radius).

(3) d equals centre for arc.

(4) DIMENSIONS

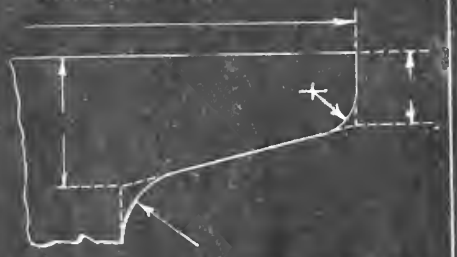
(a) 3' = 3 feet : 3" = 3 inches

(b) Small dimensions thus: ¼" or 1/16"

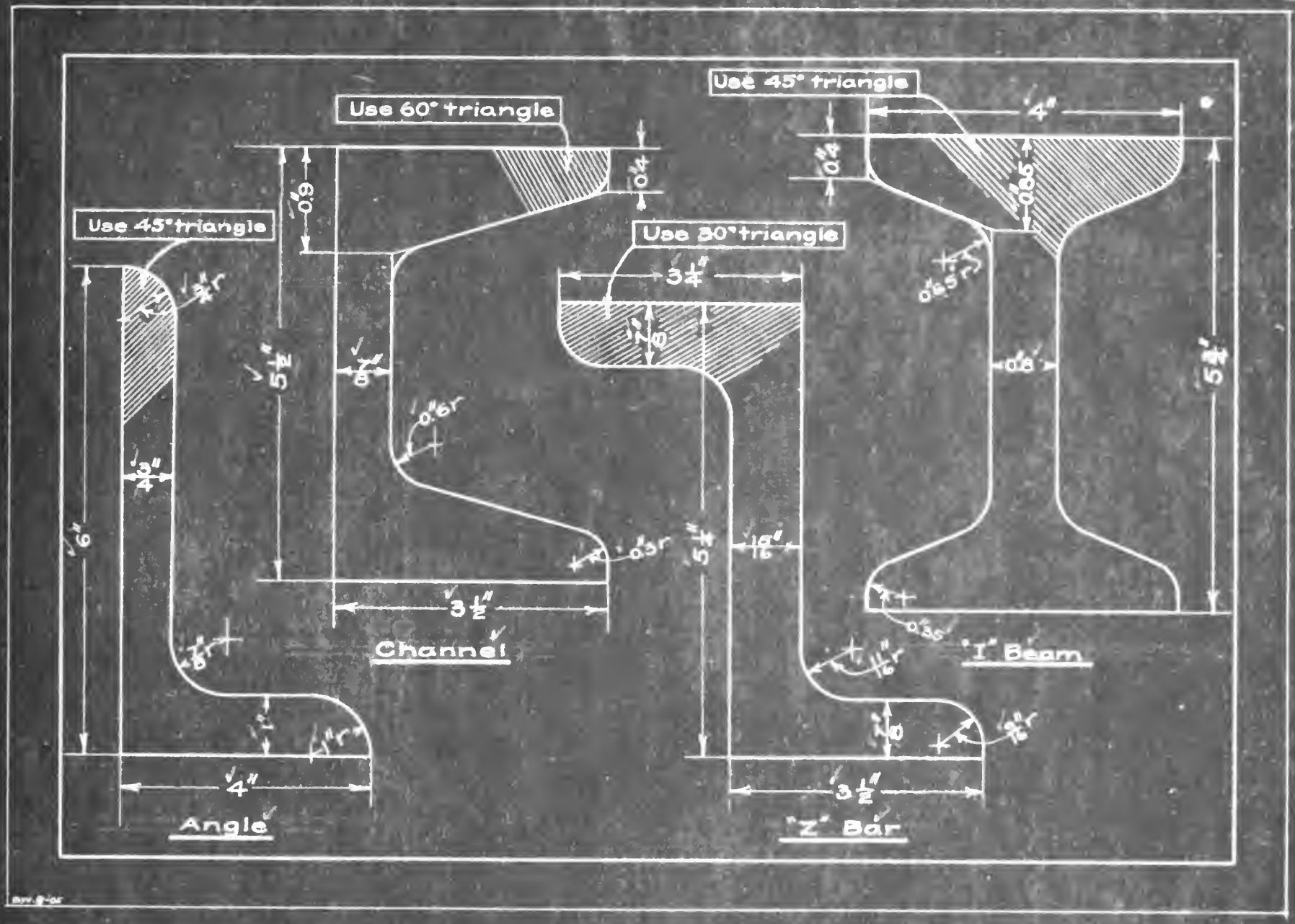
(c) Small radii thus:

(d) "Extension Lines" are used when dimensions come outside the drawing - see (5)

(5) DIMENSIONS



Extension Lines here shown dotted and are often so drawn. In this course they are to be full



Note: In Tracing (a) Omit all construction lines as shown above.

(b) Light Lines about thus ———————

(c) Medium Lines about thus ———————

(d) Heavy Lines about thus ———————

Sheet 5

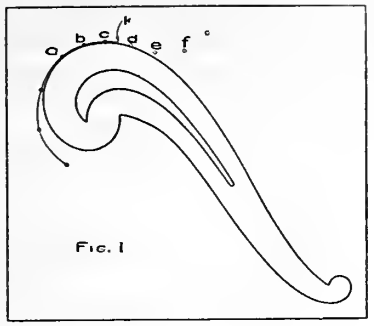


FIG. 1

Use of French Curve or Scroll

Given a series of points to be joined by a *smooth curve*.

Find portion of Scroll to fit at least **3** points (as **b, c, d**). Then draw from **b** to **k** (about half way between **c** and **d**). Change Scroll to fit **c d e**, and draw curve from **k** to half way between **d** and **e**. Continue thus.

Sometimes the Scroll will fit more than three points, but in any case stop half way between last two, as suggested above.

LECTURE DATE.....

DIRECTIONS

I. (*a*) Follow the *Order of Pencilling* given on PAGE *26*, beginning with the necessary construction lines.

(*b*) *Strengthen* only the *Outlines of Curves*. (Use "**French Curve**" or "**Scroll**" — PAGE *31*).

At ends, where French Curve does not fit the points well, short arcs may be used.

(*c*) *Ink in* (on Duplex Sheet) only the *curve outlines* (BLACK-MEDIUM) and *Border* (BLACK-HEAVY).

(*d*) *Small Circles* about *Reference Points* can be inked in *Red*. (Use *Bow Pen*.)

II. PROBLEM 1. **Ellipse** (*Exact Method*).

(*a*) Lay off line, as $\mathbf{a^1 b^1}$, equal to *Major Axis*. Use this for measuring Radii (as $\mathbf{a^1 e^1}$ and $\mathbf{b^1 e^1}$) in developing curve.

(*b*) Find at least **5** *Points* for each quadrant.

(*c*) Add explanatory equation for one point of curve, as indicated.

III. PROBLEM 2. **Ellipse** (*Approximate Method*).

When the *Major* and *Minor Axes* do not differ much in length, a simple approximate method, by means of circular arcs, can be used to replace the more complicated exact method.

Construction as shown.

IV. PROBLEM 3. **Parabola.**

Divide **a b** and **a c** each into at least **8** parts.

V. PROBLEM 4. **Hyperbola.**

(*a*) Draw the large rectangle by dimensions given.

(*b*) Begin the curve at **a**.

Find enough points to give a smooth curve.

(*c*) The divisions on **a b** *need not be* of *uniform* length.

NOTES

A. **Ellipse — Parabola — Hyperbola.**

These curves belong to the family of **Conic Sections**, so called because they are derived by the intersection of planes with the surface of a **Cone.**

Their exact derivation will be taken up in *Sheet 13*. This sheet deals merely with certain geometrical methods of drawing them.

B. PROBLEM 1.

The **Ellipse** can be defined as *the path traced by a point, the sum of whose distances from two fixed points always remains constant.*

(*a*) The two fixed points are called "**Foci**" (singular, "**Focus**").

(*b*) The long diameter or *Length* of Ellipse is called the "**Major Axis.**"

The short diameter or *Width* is called "**Minor Axis.**"

(*c*) Study above definition and PROBLEM *1*.

It will be seen that the sum of the distances from the *Foci* to the moving point will always equal the *Major Axis*. Then, with Major and Minor Axes given, the Foci can be found by drawing arc with Radius $\mathbf{R} = \frac{1}{2}$ *Major Axis*, and one end of Minor Axis as centre (see diagram).

The method of developing the Ellipse is indicated, and, as it follows the definition given above, it is called the "**Exact Method.**"

C. PROBLEM 3. **Parabola.**

(*a*) The exact definition of this curve is left for *Analytical Geometry*.

(*b*) When the width and height of the curve are given it can be drawn as indicated.

D. PROBLEM 4. **Hyperbola.**

(*a*) As in the case of the *Parabola*, the exact definition is here omitted.

(*b*) Only part of the curve is drawn by this method.
The curve, if continued, would extend upward from **a**.

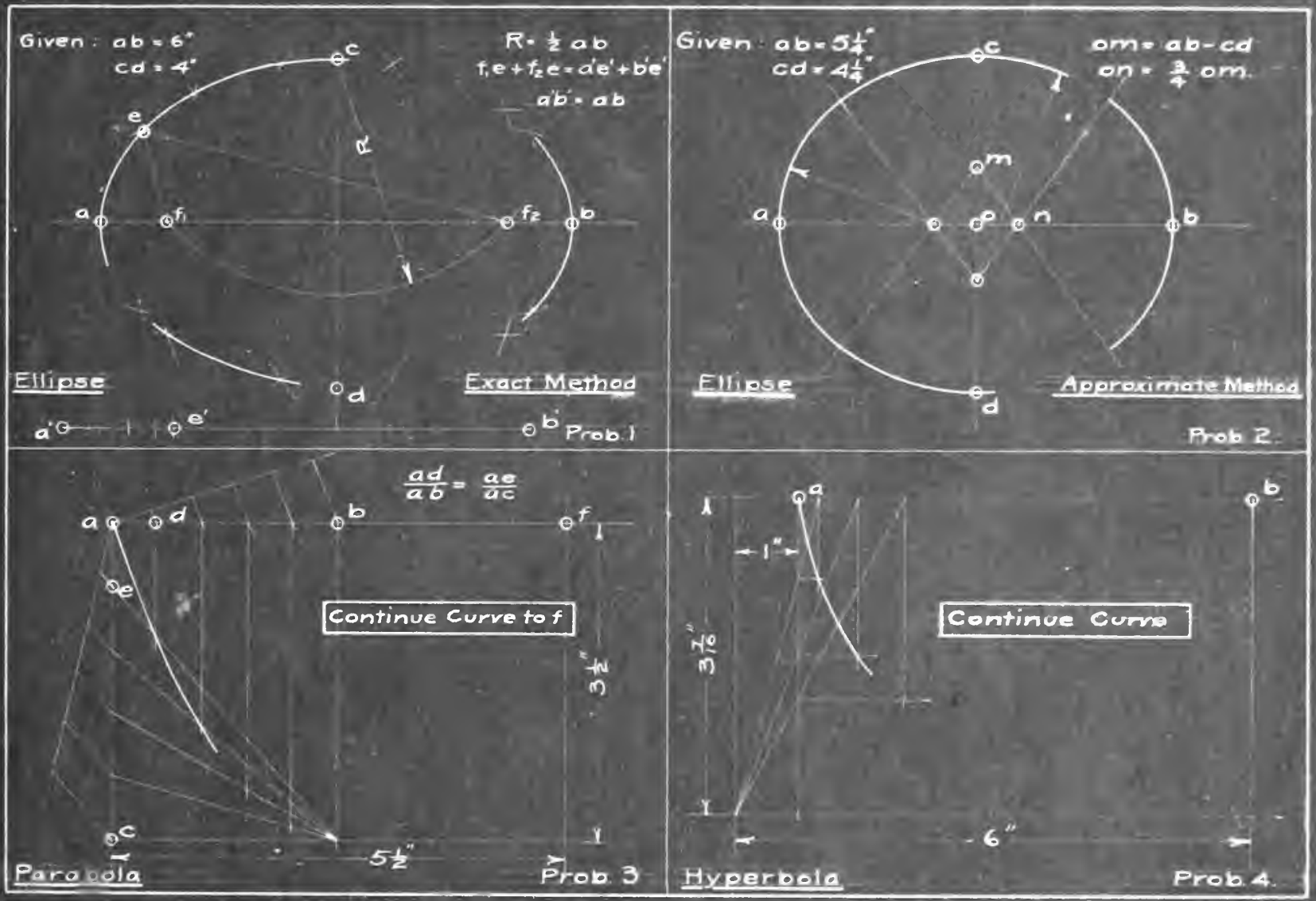
(*c*) This construction is much used in the representation of the *Theoretical Indicator Card* of a *Steam Engine*.

Questions for Consideration

(1) How would the Ellipse change if the *foci* were drawn nearer the centre?

(2) How would the Ellipse change if the *foci* were drawn farther from it?

(3) What would the Ellipse become in each of the above limiting cases?


Given : ab = 6"
cd = 4"
R = ½ ab
f₁e + f₂e = a'e' + b'e'
a'b' = ab
Ellipse
Exact Method
Prob. 1
Given ab = 5¼"
cd = 4¼"
om = ab - cd
on = ¾ om.
Ellipse
Approximate Method
Prob 2.
ad/ab = ae/ac
Continue Curve to f
3½"
5½"
Parabola
Prob 3
Continue Curve
3 7/16"
1"
6"
Hyperbola
Prob 4.

Sheet 6

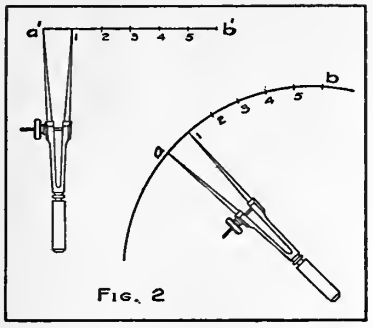


FIG. 2

To Rectify a given Arc

Given arc **ab** (FIG. 2). Use Bow Spring Dividers. Step off *short distances* along arc **ab** and same number along Straight Line.

This makes **a'b'** equal, approximately, arc **ab**.

Unit distance should be so short that the arc and chord are practically equal.

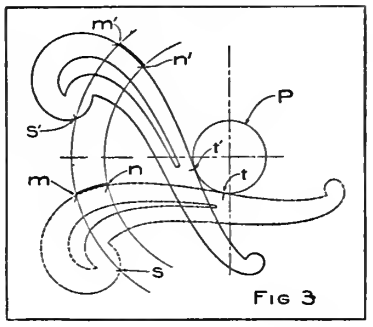


FIG 3

To Transfer a Gear Tooth Curve

Place *Scroll* to coincide with given curve (**mn**) (FIG. *3*). Mark point **n** on Scroll and draw *Circle* **P** tangent to Scroll at any convenient point (as **t**). Change Scroll to new position and draw **m'n'** as shown.

Alternative Method

Omit *Circle* **P** and use mark (as **s**) to locate curve.

LECTURE DATE.....

DIRECTIONS

I. Begin construction by laying out *Centre Lines* of circles. Draw all construction circles *very light*.

II. PROBLEM 1.
- (*a*) Make *Rolling Circle* (**R. C.**) = **2**″ diam.
- (*b*) Use **8**, **10** or **12** points on **R. C.**
- (*c*) In stepping off distances on circles use *small Dividers*.

(See PAGE *35*–FIG. *2*.)

III. PROBLEM 2.
- (*a*) Make **R. C.** for *Epicycloid* = $1\frac{3}{4}$″ diam.
- (*b*) " " " *Hypocycloid* = $2\frac{1}{4}$″ diam.
- (*c*) Use **10** or **12** points on R. C. for both curves.
- (*d*) Transfer curves to make gear teeth.

(See PAGE *35*–FIG. *3*.)

IV. PROBLEM 3.
- (*a*) Take points about **15°** apart on the circumference.
- (*b*) To draw tangents, see PAGE *6–D–c*.

V. Strengthen outlines of *Curves* and *Gear Teeth* only.

VI. INK IN: —
- (*a*) *Curves* and *Gear Teeth*. (BLACK-MEDIUM.)
- (*b*) Small *Reference Circles*. (RED.)
- (*c*) *Border line*. (BLACK-HEAVY.)

Questions for Consideration

(1) When the curve of Problem 1 comes back to the straight line, how far will it be from the initial point **O**? (Answer by showing proper dimension line and figures.)

(2) If the diameter of the Rolling Circle for the *hypocycloid* were increased, how would the resulting curve change?

(3) If the diameter becomes = radius of Pitch Circle, what kind of a curve would result?

NOTES

A. **Cycloid, Involute, Epicycloid, Hypocycloid.*** These curves belong to the family of **Cycloids.** They may all be defined as *the path traced by a Point on the Circumference of a Circle which rolls on a given Line* (either Straight or Curved).

B. PROBLEM 1. **Cycloid.**
Rolling Circle (**R. C.**) rolls on a *Straight Line*.
- (*a*) Take points on initial position of **R. C.**
- (*b*) Find successive positions of **R. C.** by making distance **O–1** on **A B** = **arc O–1** on **R. C.**, etc.

(See PAGE *35*–FIG. *2*.)

- (*c*) Locate the successive positions of **O** by stepping off the proper arcs in the direction of the arrows.

The length of these arcs will, in each case, be the distance over which the circle has rolled. To verify this, try a coin rolling along the edge of the **T**-square.

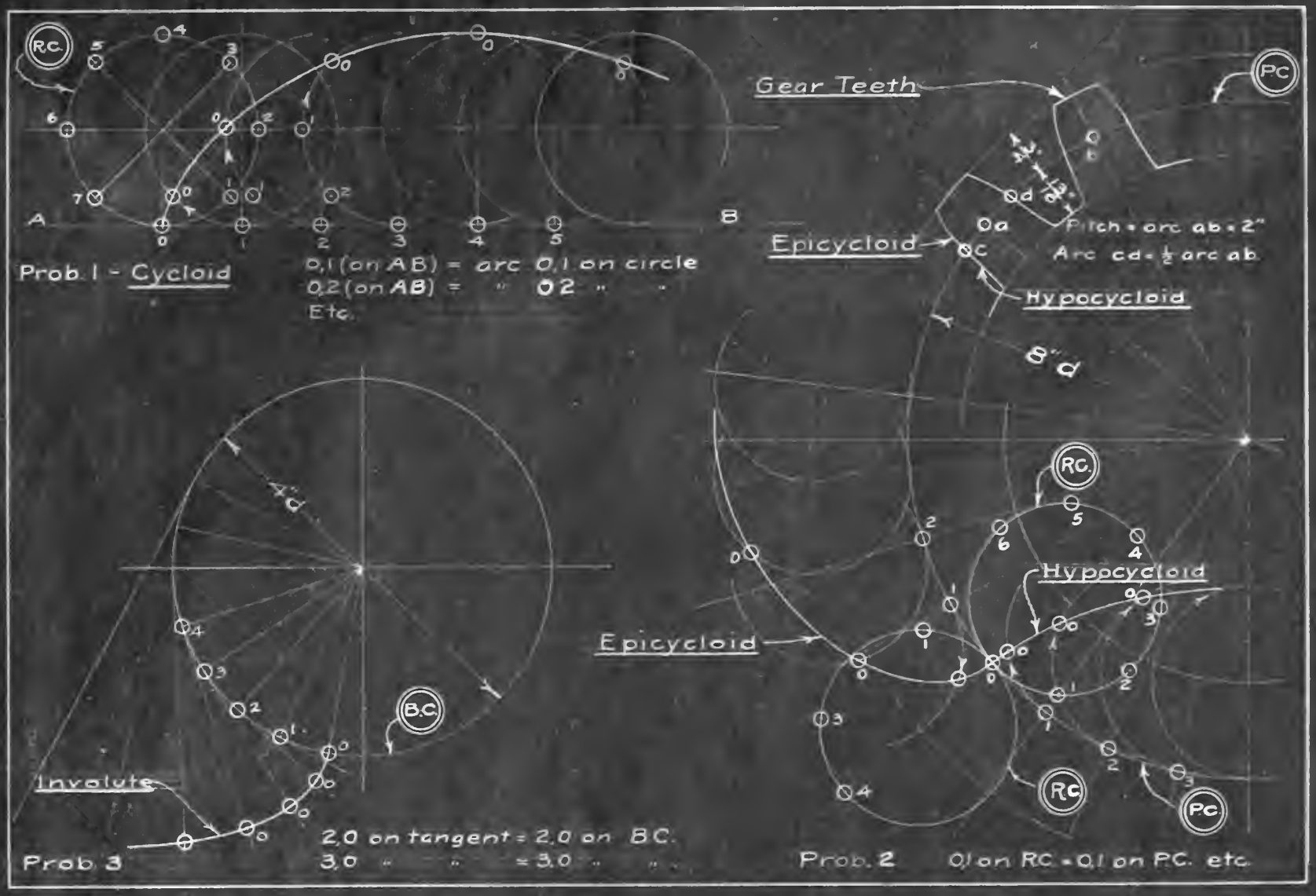
C. PROBLEM 2. **Epicycloid and Hypocycloid.**
Former = **R. C. outside** of another *Circle*.
Latter = " **inside** " "
- (*a*) Construction similar to PROB. 1.
- (*b*) **Gear Teeth** are formed by *Epicycloids* and *Hypocycloids* drawn, respectively, *outside* and *inside* a circle known as "**Pitch Circle.**" The "**Pitch**" of the teeth is the distance between the centres of successive teeth, measured along the *Pitch Circle* (are **a b** in diagram).

D. PROBLEM 3. **Involute.**
Straight Line (Circle of Infinite Radius) rolls on a *given circle*. (Hence a special case of the Epicycloid).

More simply — a string, held taut, is unwound from a cylinder or drum (represented by given circle). End of string describes *involute*.

The String is taken in successive positions by drawing tangents at end of successive radii, and the proper distances are stepped off as shown.

* Cycloid — *κύκλος* = "*Circle.*"
Epicycloid — *ἐπι* = "*upon*" + *κύκλος*.
Hypocycloid — *ὑπό* = "*under*" + *κύκλος*.
Involute — (Latin) **in** = "*upon*" + **volvo** = "*to roll.*"



7-25-24

Note: (P.C.) = Pitch Circle (B.C.) = Base Circle (R.C.) = Rolling Circle.

4"d means 4 inches diameter.

CONTINUE ALL CURVES AS FAR AS POSSIBLE WITHOUT CONFLICT.

Sheet 7

LECTURE DATE

I. **Orthographic Projection**, described simply, is a method of delineating an object accurately and adequately by means of one or more views, so grouped as to be easily read together, and thus give a clear idea of the form and dimensions of the object.

The technical development of **Projections, Projection Planes**, etc., is left for later consideration (see PAGE *123*).

II. EXAMPLE: **House.** (See PAGE *41*.)

(*a*) Let **F. V.** = *Front View*. **R. V.** = *Right Side View*.
T. V. = *Top View*. **L. V.** = *Left Side View*.

(*b*) If we stand far enough away so that the rays from all points of the house to the eye are practically *parallel*, we can reproduce on paper, to a convenient scale, the corresponding appearance of the house.

Place this so-called **View** at the bottom and centre of a sheet of paper and label it **F. V.** (*Front View*).

Now walk around and look at the house from the **Right Side**. Place this *View* to the *Right* of **F. V.** and label it **R. V.** (*Right Side View*).

Similarly place **L. V.** (looking at house from *Left Side*) as shown.

Now look at the house from **above** and place view obtained above **F. V.**, labelling it **T. V.** (*Top View*).

(*c*) Select as an axis of reference the **Centre Line** of the house (*C. L.*).

Note the abbreviations **R** and **L** for *Right* and *Left* of Centre Line.

Note also that any given point on the house has the same number *in all views*.

III. Then **Note Carefully**:—

(*a*) Point **1** lies on *same horizontal line* in **F. V.**, **R. V.**, and **L. V.**

(*b*) Point **1** of **T. V.** lies *vertically above* Point **1** of **F. V.**

(*c*) (Looking at **T. V.** in the direction of arrow **M** and comparing with **R. V.**) — Point **1** lies on the *same side* (**Left**) of Centre Line and at *same distance** (**A**) from it in both views.

Similarly (looking in direction **N** and comparing **T. V.** with **L. V.**) — Point **1** lies at distance* (**A**) on the **Right** side of Centre Line in both views.

IV. The above relations constitute the 3 WORKING PRINCIPLES OF ORTHOGRAPHIC PROJECTION. They can be summed up thus:—

(1) The **front** and **side** views of a point on the object lie in the same *horizontal* line.

(2) The **front** and **top** views of the point lie in the same *vertical* line.

(3) The **top** and **side** views of the point lie on *corresponding* sides of the Centre Line (Right or Left) and at the *same distance** from it.

V. (*a*) By means of the above analysis, with *two Views* of an object given, we can usually locate the position of corresponding points in a *third* or *fourth View*, and thus complete these views.

PROB. 1 of Sheet 8 requires this to be done. Method shown by FIG. 4 on PAGE *41*.

(*b*) Any view of an object may be taken as a **F. V.**, but having selected and located this, we must group the other Views about it in accordance with the above principles (**T. V.** always at **Top** — **R. V.** always at **Right**, etc.).

If necessary we could develop a *Bottom View* which would then be placed *below* the **F. V.** (See FIG. 2 on PAGE *41*.)

(*c*) In general, *three Views* are enough to clearly describe an object (as will be seen in example above), but where necessary, *four* or even *five* Views may be taken.

(*d*) *Hidden Lines* are represented dotted, as shown.

(*e*) Note that above principles apply to views of the Lamp (FIG. 3 on PAGE *41*) and to views of points on it.

* Distance is always measured *perpendicular* to Centre Line.

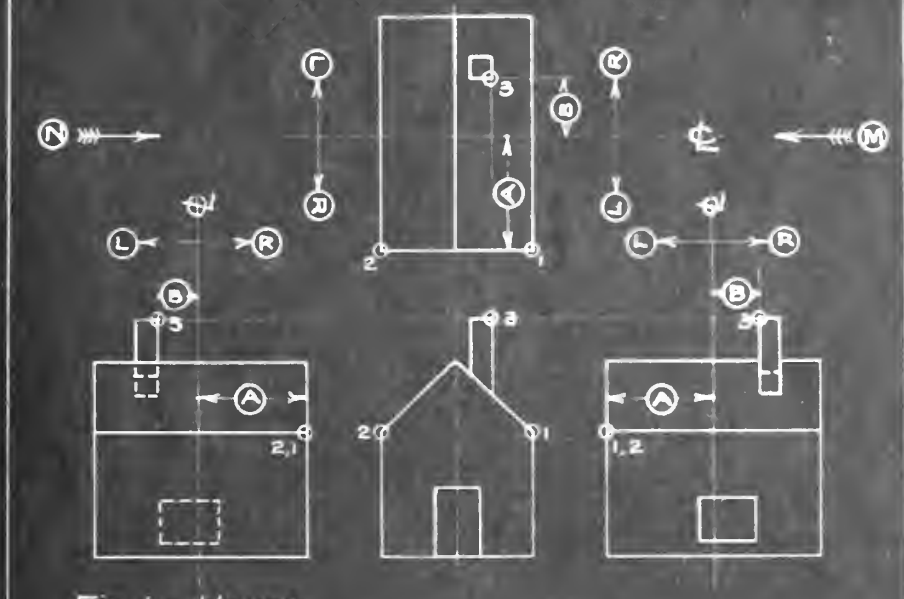


Fig. 1 - House

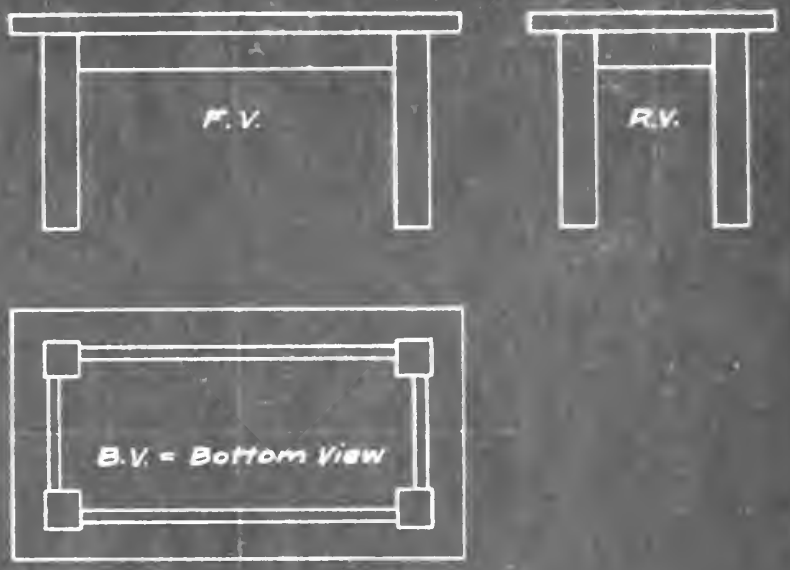


Fig 2 - Table showing bottom view.

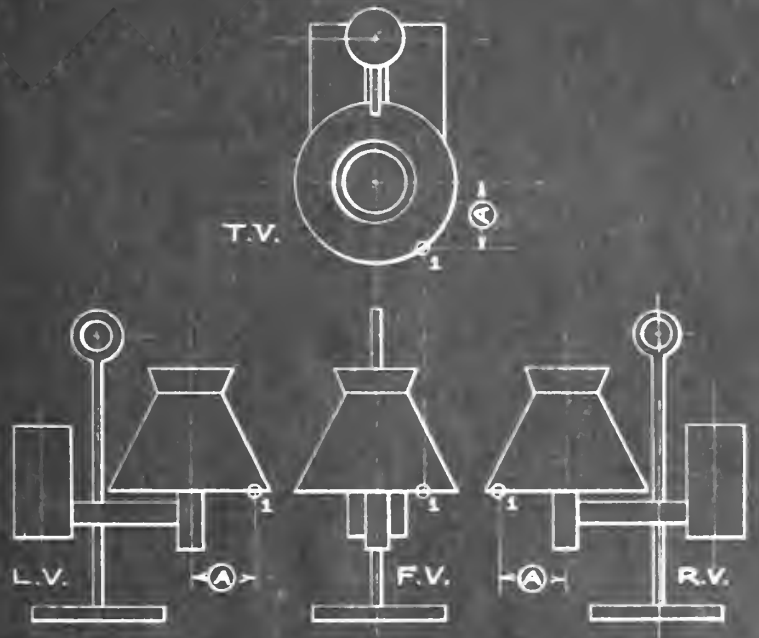


Fig3 - Lamp

T.V. and R.V. being blocked out, to draw R.V.

(1) Draw lightly lines I and II

(2) In R.V. set off, from ℄, distances III, IV, V and VI obtained from T.V.

(3) Join points with lines VII, VIII, IX

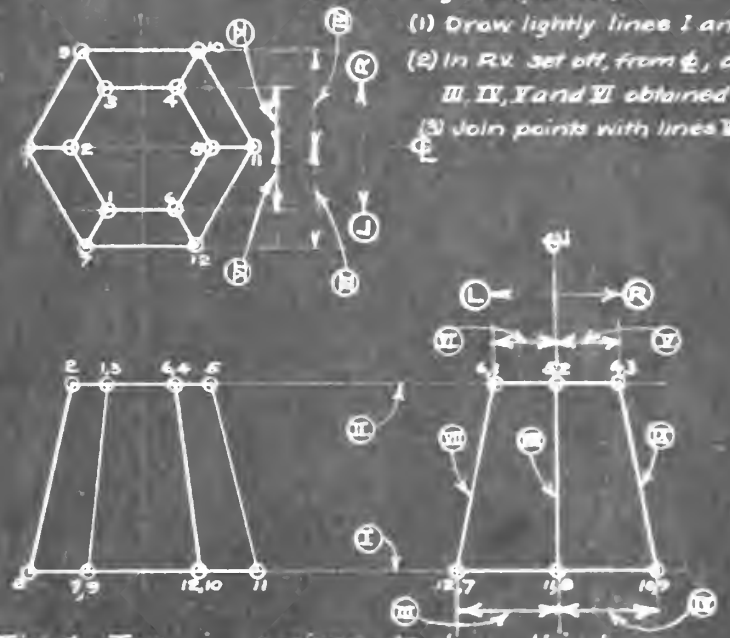


Fig 4 - Two views given, to draw third.

THIS SHEET IS FOR ILLUSTRATION ONLY

LECTURE DATE.....

DIRECTIONS

I. Study carefully PAGES *40* and *41*. Apply principles there explained to the development of the following problems: —

II. PROBLEM 1.
- (*a*) Lay out Centre Lines. ‡
- (*b*) Block out **T. V.** (Draw hexagon by EX. 1 on SHEET *3*).
- (*c*) " " **F. V.**
- (*d*) " " **R. V.** as explained by FIG. 4 on PAGE *41*.

III. PROBLEM 2.
- (*a*) Lay out Centre Lines.
- (*b*) BLOCK OUT ALL THREE VIEWS TOGETHER.
  (Draw pentagon by method of PAGE *113* — making circumscribing circle $1\frac{3}{4}''$ diam.)

IV. PROBLEM 3.
- (*a*) Proceed as in PROB. 2.

V. PROBLEM 4.
- (*a*) Same procedure.
- (*b*) The subject is the same as PROB. 3, turned through an angle of 30°.

NOTE: **We still use Horizontal and Vertical centre lines.**‡

VI. Strengthen Outlines. (See note A–*a* on this page.)

VII. OMIT ALL DIMENSION LINES AND FIGURES ON THIS SHEET.

VIII. EXPLAIN CONSTRUCTION.
In each problem locate *three views* of one *Reference Point* and indicate the correspondence of these views as suggested by note **C** on this page.

IX. Ink in *only*: —
- (*a*) All centre lines (*Red-light*).
- (*b*) Circles about Reference Points (*Red*).
- (*c*) Circles about "**R**" and "**L**" (*Red*).
- (*d*) Border line (*Black-heavy*).

Questions for Consideration

(1) On the object of PROBLEM 1 how many edges are there? Can you account for them all in *every* view?

(2) **T. V.** of an object is represented by a circle inside of a square. What different *front views* are consistent with this **T. V.**?

(3) **F. V.** of an object consists of three concentric circles. What *side views* can be drawn?

(4) With the inmost circle *dotted*, what *side views* can be drawn?

(5) Can any view of a curve be a straight line?

NOTES

A. Follow the **Order of Pencilling** given on PAGE 26.

(*a*) It is usually wisest to block out the entire sheet before beginning to strengthen any outlines.*

(*b*) As far as possible, develop all views of an object together† instead of completing one view before beginning another.

(*c*) In "Strengthening" HIDDEN LINES are *dotted*.

(When Blocking out draw hidden lines light and full: a light "*d*" placed on them will indicate that they are to be dotted later.)

B. PROBLEM 3.

(*a*) The drawing represents a **Block** with a **Round Hole** in it, and a **Triangular Prism** on top.

(*b*) The bottom lines of the hole can be drawn with the 30° Triangle.

C. **Explanation of Construction** should be added to all pencil sheets from now on.

A simple and satisfactory method suggested is to select a certain number of typical "**Reference Points**" and to identify them in all views by numbering and by small circles in red ink (as shown on PAGE *41*). *Points different from those given on the blue print* should always be selected.

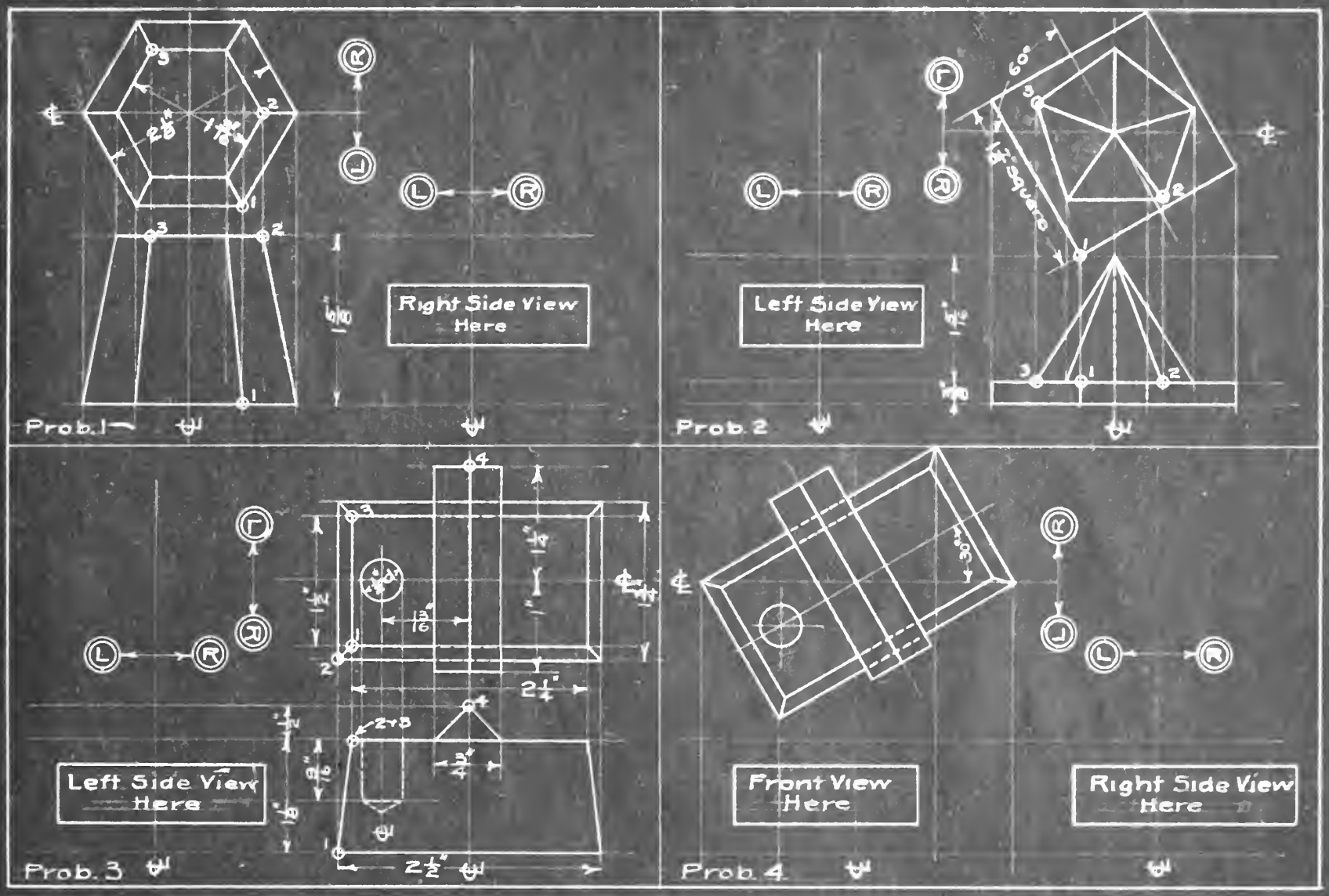
The correspondence of the chosen points according to the first two *Principles of Projection* (PAGE *40*–V) can be indicated by red ink lines from Front to Top and Side views of each point.

The correspondence of distances in Top and Side views (third Principle) can be indicated by "**Reference Distances**" (using a letter instead of figures) as shown by distance **A** in FIG. *1*, PAGE *41*. *Reference Distances* can be used to explain other relations also, in later sheets.

* This method assists, particularly later on, in gauging the best arrangement of the drawings on a sheet, and prevents unnecessary erasure in correcting the arrangement.

† This will be found to economize time and to assist in understanding the relation of the various views. Where a horizontal line is to appear in **F. V.** and **R. V.** or **L. V.** draw it, at one stroke, through both views.
Similarly for vertical lines in **F. V.** and **T. V.**

‡ **Centre Lines** are not restricted to **T. V.** and **R. V.** but are drawn at the outset in any view that is in general symmetrical. Subordinate parts (if symmetrical) also have Centre Lines, *e.g.* "hole" in PROBLEM 3.



Note: (a) Be careful to note whether or not corresponding reference points are correctly located and numbered in above print. If any correction is necessary, make it in red ink on the blue print.

(b) Make dotted lines about thus: — — — — —

Sheet 8

ORTHOGRAPHIC PROJECTIONS—TRUE SIZES AND TRUE LENGTHS *(continued)*

LECTURE DATE.....

SHEET 9

ORTHOGRAPHIC PROJECTIONS—TRUE SIZES AND TRUE LENGTHS (*continued*)

DIRECTIONS

I. Proceed as in Sheet 8.

(*a*) Lay out *Centre Lines*.

It is best to lay out also Centre Lines of symmetrical parts like the chimney (see distance **A**) so that points on it (**1** and **4** for instance) can be measured equal distances right and left of its own Centre Line.

(*b*) Block out all 4 Views together. (**Stage 1.**)

(*c*) Develop drawing and Strengthen Outlines of all 4 Views. (**Stage 2.**)

(*d*) Draw Dimension Lines and Arrows. (**Stage 3.**)

(*e*) Put in Figures and Lettering. (**Stage 4.**)

II. Explain Construction.

As suggested by note C on Page *44*, identify all views of *two* Reference Points and indicate by Reference Distance (as **D** for point **2**) how they were located in a True Size. *Do not use the points given on the blue print.*

III. Ink in, as hitherto:—

(*a*) Centre lines. (*Red-light.*)

(*b*) Circles about Reference Points and Letters.* (*Red.*)

(*c*) Border line. (*Black-heavy.*)

* "**A.**" "**B,**" "**L,**" "**R,**" etc., are "*Reference Letters.*"

NOTES

A. (*a*) Use edge of Scale marked "$\frac{1}{4}$." This gives graduations corresponding to $\frac{1}{4}$ *inch* = 1 *foot*, which is the Scale called for in the drawing.

(*b*) **18′–3″** means **18** *feet*, **3** *inches*, etc.

B. In the blue print all lines have been drawn *full*. Remember that Hidden Lines are *dotted*.

In Strengthening, therefore, correct the lines of the blue print wherever necessary.

C. Walls are considered as having no thickness, and *Door* and *Window* as open.

D. To show the "**True Size**" of a roof plane or part of it (as hole for chimney), a new view must be taken—*perpendicular* to the plane of the roof.

Each distance used in drawing it must be taken from some view where that distance is seen in its "*true length.*"

Questions for Consideration

(1) In getting *true size* can all the distances come from one view? Why?

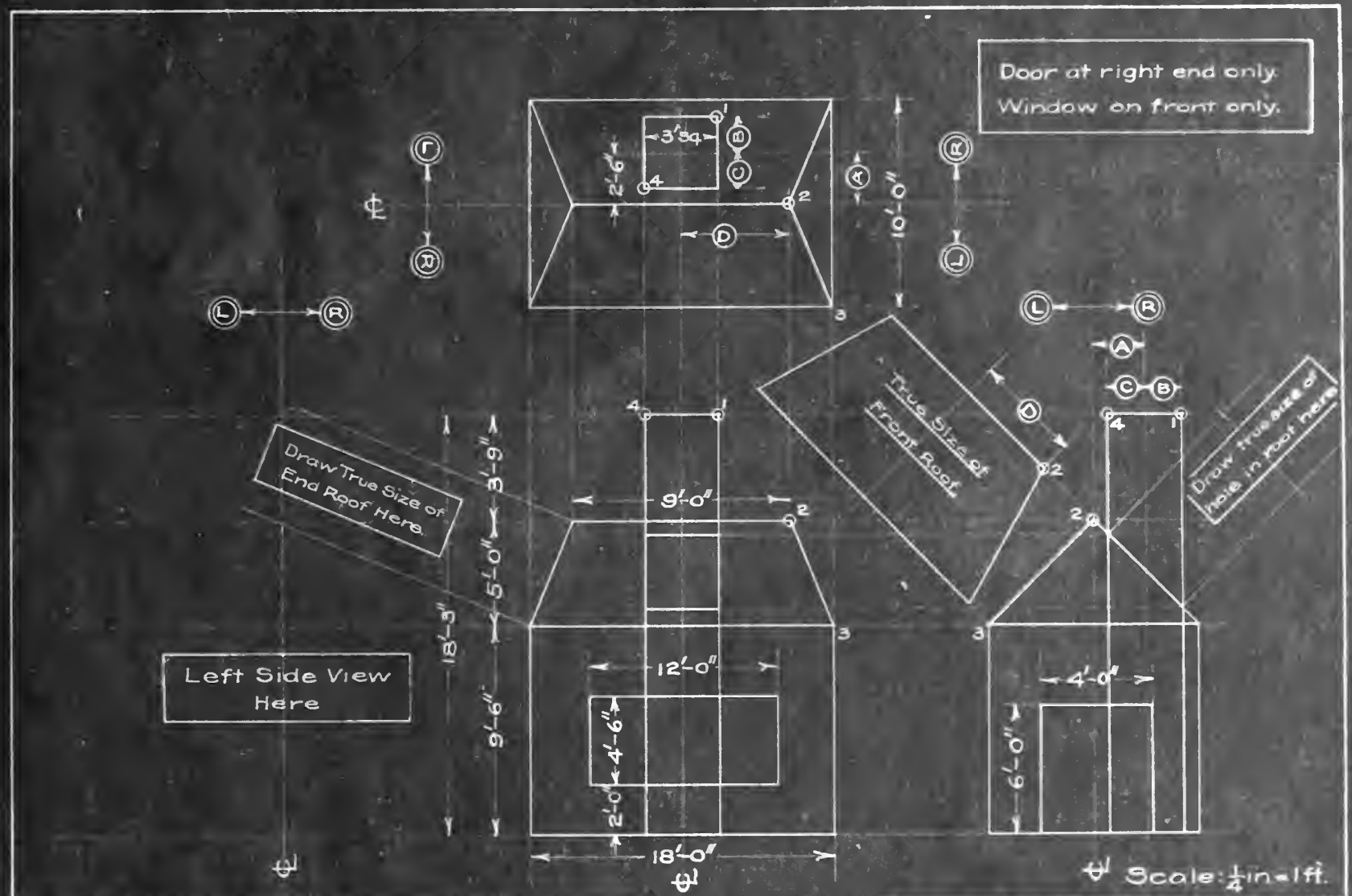
(2) What kind of a view must be taken to see a line in its *true length?*

(3) How could the *true length* of the hip rafter (**2–3**) be found without drawing the true size of the whole roof?

(4) Under what conditions can a *view* of a line be (*a*) shorter than, (*b*) equal to, (*c*) longer than, the line itself.

(5) What is the shortest view a line can have?

(6) As suggested by questions 4 and 5, what are the limiting cases of the views of a plane surface, say a rectangle?


Door at right end only.
Window on front only.
3'-3"
2'-6"
2'-0"
9'-0"
12'-0"
4'-6"
2'-0"
18'-0"
18'-3"
9'-6"
5'-0"
3'-9"
4'-0"
6'-0"
Draw True Size of End Roof Here.
Left Side View Here
True Size of Front Roof
Draw true size of hole in roof here
Scale: 1/4 in = 1 ft.

LECTURE DATE.....

DIRECTIONS

I. Follow directions for Sheet 9.

II. Substitute for "?" the proper dimension figures taken from Sheet 9.

Note that the location of some dimensions has been changed, as a line should **only be dimensioned where it appears in its True Length.**

III. EXPLAIN CONSTRUCTION.
Identify all views of three *Reference Points*, one of which is on the intersection of roof and chimney.

Indicate, by *Reference Distances*, how this point was obtained.

IV. INKING. Same as hitherto.

NOTES

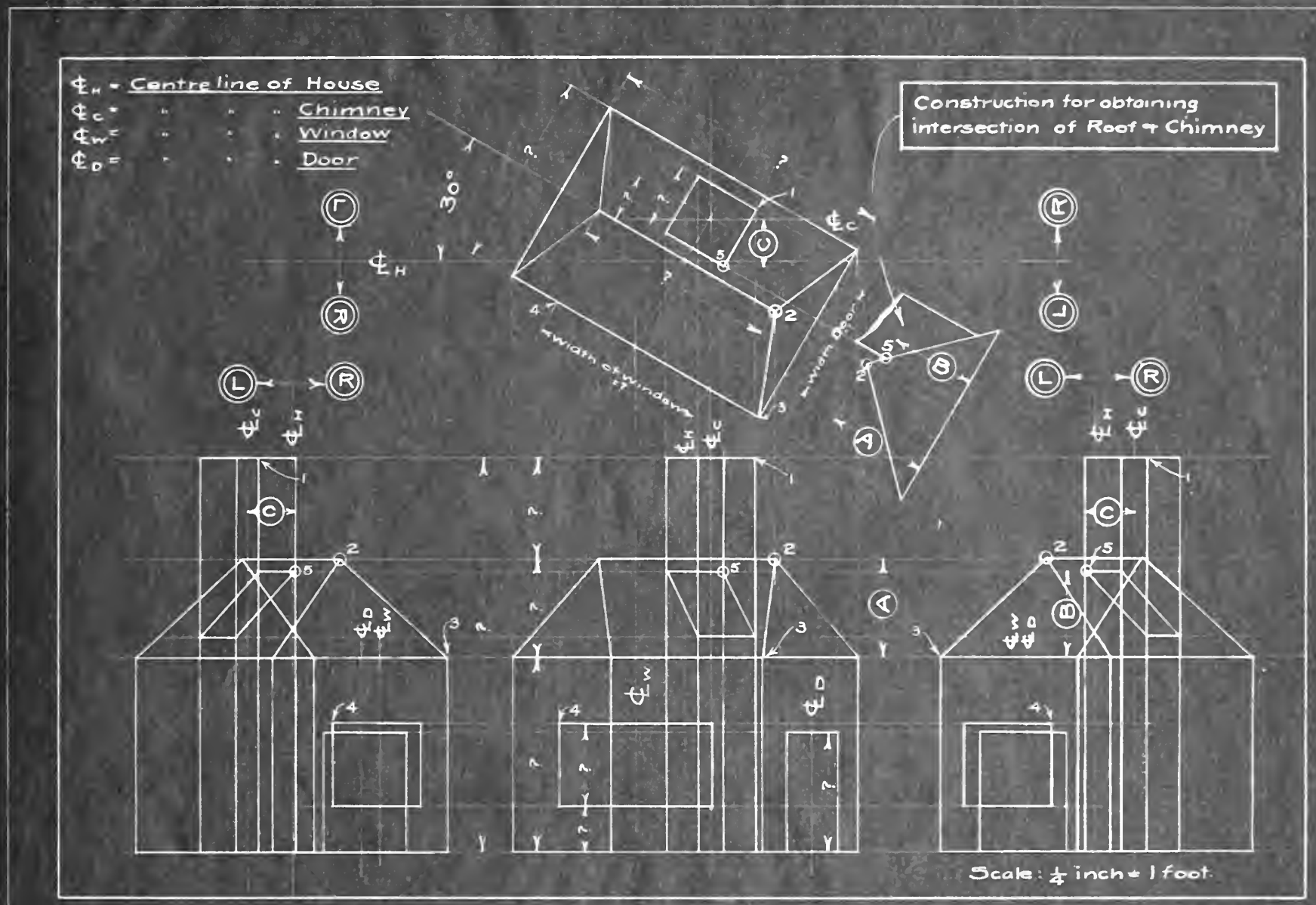
A. This sheet shows the subject of Sheet 9 turned through an angle of 30°.

B. Remember, as before, that *Hidden Lines* are to be shown *dotted*.

Questions for Consideration

(1) With views as here given, how would you find the true length of the hip rafter (**2–3**)?

(2) How would you find the true size of end and side of roof and of hole in roof?



Note: Be careful to note whether or not corresponding reference points are correctly located and numbered in above print. If any correction is necessary make it in red ink on the blue print.

Sheet 10

SHEET 11

INTERSECTION OF PRISM AND PYRAMID BY PLANE — DEVELOPMENT

LECTURE DATE.....

SHEET 11

INTERSECTION OF PRISM AND PYRAMID BY PLANE — DEVELOPMENT

DIRECTIONS

I. PROBLEM 1. **Truncated Prism.**

(*a*) Work out *Front*, *Top*, and *Side Views* of subject.

(*b*) Obtain *True Size* of top, as shown.

(*c*) Draw a **Development** of the resulting surface. (See note B of this page.)

II. PROBLEM 2. **Truncated Pyramid.**

(*a*) Show first the Pyramid as it appears before it is cut off.

(*b*) Then draw *Cutting Plane* and proceed as in PROBLEM 1.

III. For both problems.

(*a*) *Order of Pencilling* same as before.

(*b*) Number neatly every point of the object *in all views* and in Development, for purposes of identification during construction.

In cases where confusion is likely to occur, use *arrows*.

IV. EXPLAIN CONSTRUCTION.

In both problems identify at least two *Reference Points* in all views, true size, and Development. Indicate by *Reference Distances*, as suggested on the blue print, how these points were obtained.

In PROBLEM 2, also indicate how true lengths of (**1–4**) and (**3–4**) were obtained and used in Development.

V. INKING same as hitherto.

VI. Reproduce both *Developments* on piece of *Duplex Paper*. Cut out and fold to produce original objects.

NOTES

A. From now on, with the exception of SHEET *17* (Isometric Drawing), all the problems and sheets of the course are based on the principles of *Orthographic Projection*. This term will, therefore, be omitted from the heading of the following sheets, and the title only of the special problem on each sheet will be given.

B. Given an object, like an irregular Box, to find the *size* and *shape* of a *sheet of material* which, when folded, will produce the object.

The solution of this problem is indicated on this sheet. The technical term by which this process is known is: —

Development of a Surface.

C. PROBLEM 2.

(*a*) The Front View does not show the slanting edges of the Pyramid in their *true length* as needed for the Development.

(*b*) To be seen in its "*true length*" a line must be perpendicular to the direction of sight. Hence "revolve" the line into such a position.

Method as follows: (*See diagram at bottom of blue print.*)

Let **ab** = **F. V.** of given Line.

" $\mathbf{a^1b^1}$ = **T. V.** " "

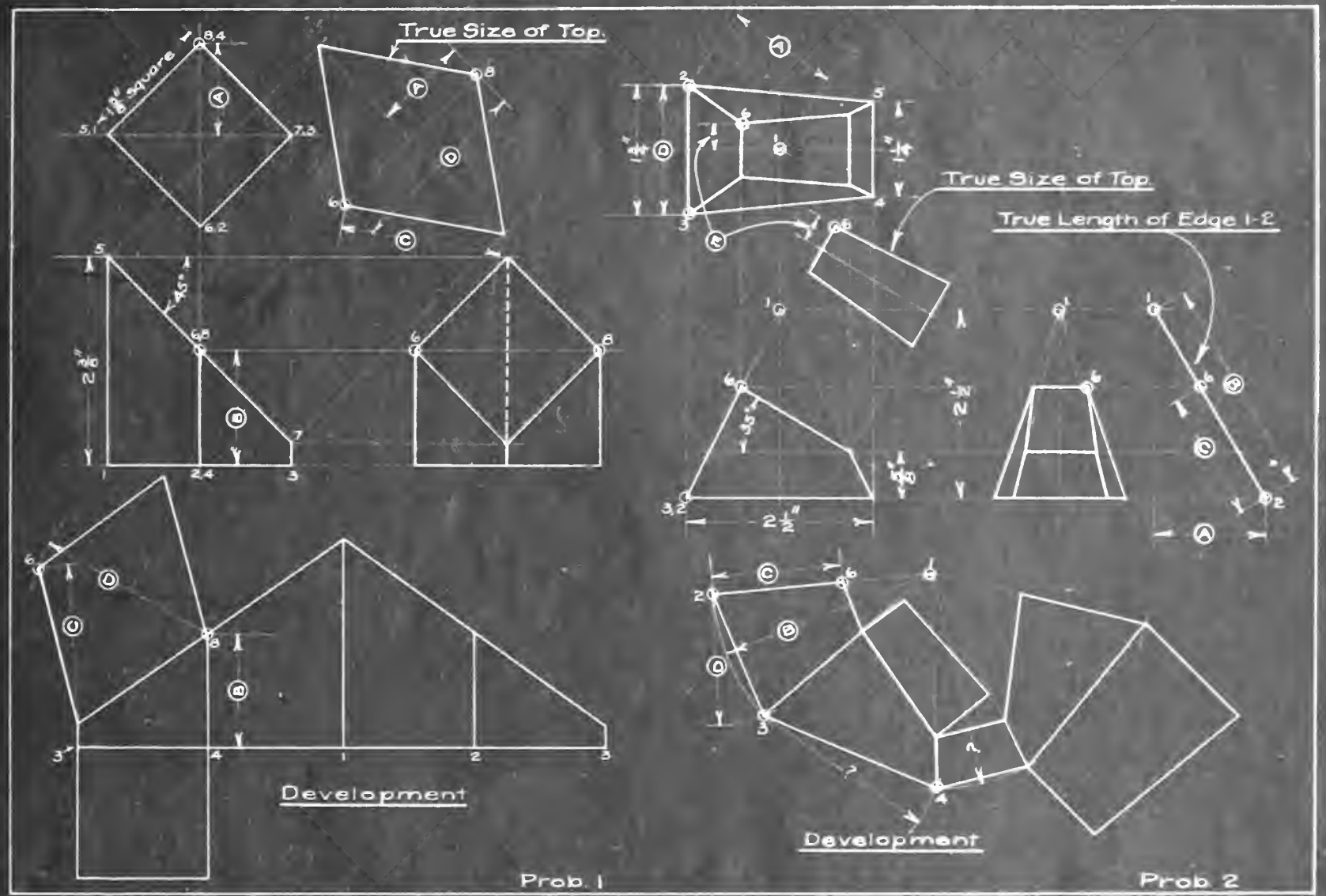
Suppose it is desired that **F.V.** shall show true length.

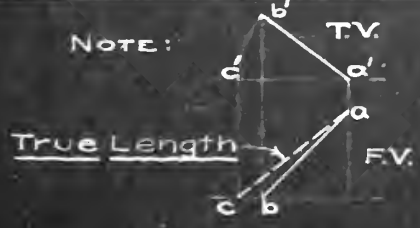
Revolve bottom ($\mathbf{b^1}$) of line to ($\mathbf{c^1}$). (Thus the whole line is revolved.)

ac will then be **True Length** of the line.

(*c*) More simply by using distances **A** and **B** in connection with altitude as shown for the edge (**1–2**).

The 60° Triangle will serve as a model of the above. As it stands vertically on the table, the "long," "short," and hypothenuse sides represent respectively the altitude, distance **A**, and true length.


True Size of Top
Development
Prob. 1
True Size of Top
True Length of Edge 1-2
Development
Prob. 2


NOTE:
T.V.
True Length
F.V.

Sheet 11

LECTURE DATE.....

DIRECTIONS

I. Draw 3 views of Cone and locate Elements by Auxiliary Planes.

At least 12 Elements will probably be found necessary. They can be lettered, as indicated, for convenience of identification during construction.

II. Across **F. V.** draw a line representing the *Cutting Plane.*

III. Construct **T. V.** and **R. V.** of curve of intersection. Points where *Cutting Plane* passes through each element are found and joined with French Curve.

IV. Construct **Development.**

(*a*) Lay out arc with radius = true length of elements. (Since all points of the base are at the same distance from the apex.)

(*b*) On this step off distances **3–4**, etc., from **T. V.** (Total length of arc is, of course = circumference of base.)

(*c*) Lay up on each element the true lengths **E**, **F**, etc., and draw curve.

V. EXPLAIN CONSTRUCTION, as indicated, for two Reference Points.

NOTES

A. If a cone is cut off by a plane the "**Cutting Plane**" will intersect the surface of the cone in a curve, successive points of which can be found thus:

(*a*) In order to carry out a construction on any curved surface like this, we must first locate certain lines lying in the surface in such a way that they can readily be identified in all views, and then *upon these lines* work out the required construction.

To obtain such lines in the surface of this cone, we can use *vertical* "**Auxiliary Planes**" through its axis. These will cut in the surface of the cone straight lines which run from the vertex to points in the base circle and can thus be identified in all views. These lines are called "**Elements.**"

(*b*) The problem now becomes simply to find at what point* each *Element* is cut off by the Cutting Plane, and then to identify this point in the other views. By joining consecutive points found in this way we draw the required curve of intersection.

B. The Cone may be considered as a Pyramid of an infinite number of sides.

(*a*) The base polygon of the pyramid becomes a circle.

(*b*) The surface between the edges become the smooth Conical Surface.

(*c*) The edges of the Pyramid become the Elements of the Cone.

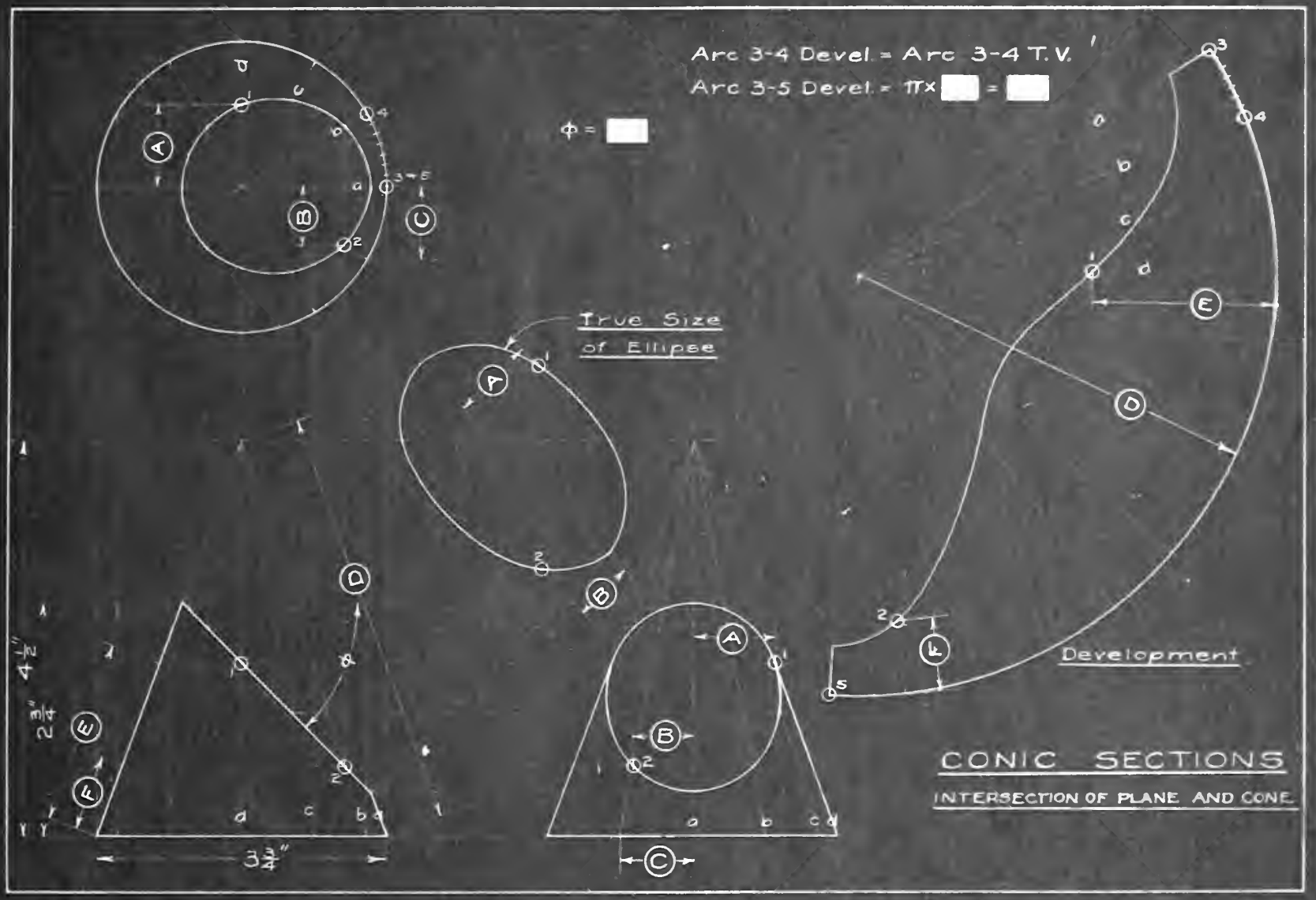
C. Heuce the method of construction, after the Elements are located, follows closely that given for the pyramid of Sheet 11.

D. As long as the *Cutting Plane* passes entirely *across* Cone, any angle ϕ will give an *Ellipse.*

Questions for Consideration

(1) How small can angle ϕ be to still give an Ellipse?
(2) " large " " " "
(3) What curves are produced iu these two limiting cases?

* The point where an Element is cut off must first be found in a view where the Cutting Plane is seen "edgewise" and appears as a straight line. This line is called a "trace" of the plane.


Arc 3-4 Devel. = Arc 3-4 T.V.
Arc 3-5 Devel. = π x ▭ = ▭
Φ = ▭
True Size of Ellipse
Development
CONIC SECTIONS
INTERSECTION OF PLANE AND CONE
4 1/2"
2 3/4"
3 3/4"

LECTURE DATE .....

DIRECTIONS

I. Draw outlines of Cone in **F. V.**, **T. V.** and **L. V.**

II. Show on **F. V.** the 4 **Cutting Planes** which produce the circle, ellipse, etc.

III. Construct **T. V.** and *True Size* of each curve* by means of **Auxiliary Planes.** (See note B.)

As many Auxiliary Planes can be used as found necessary.

In this problem they may be taken about ¼ inch apart on **F.V.** with an extra one near the ends of ellipse, etc., to give smooth curves.

COMPLETE ALL THE CURVES.

IV. EXPLAIN CONSTRUCTION.

(*a*) In red ink draw the *trace* of one Auxiliary Plane.

(*b*) Locate one *Reference Point* in each Conic Section given by this Auxiliary Plane and indicate by *Reference Distance* the correspondence between True Size and **T. V.**

V. Details of procedure same as hitherto.

* It is suggested that the Ellipse be worked out first, in order that the method may be compared with that of Sheet 12.

NOTES

A. *Planes* cutting the *Surface of a Cone*, at different angles, produce corresponding curves of intersection, called "**Conic Sections,**" as suggested on Sheet 13.

(*a*) *Plane parallel to axis of Cone* — **Hyperbola.**

(*b*) " " " *slanting Element* — **Parabola.**

(*c*) " *crosses Cone* — **Ellipse.**

(*d*) " *perpendicular to axis* — **Circle.**

In the case of the *Hyperbola* we get *two curves*, the second one inverted, if we consider the plane to cut the Cone produced above the apex.

Further consideration of *Conic Sections* is left for Analytic Geometry.

B. (*a*) As in Sheet 12, a curve of intersection cannot be found until lines lying in the surface of the cone have been located and identified in all views.

To do this we again use *Auxiliary Planes*, this time *perpendicular* to the axis of the cone, and obtain *circles* as the required lines. Note that the circle given by Auxiliary Plane P is seen in **T.V.** in its true size, but appears in **F.V.** as a straight line. (See bottom of PAGE 65–FIG. 1.)

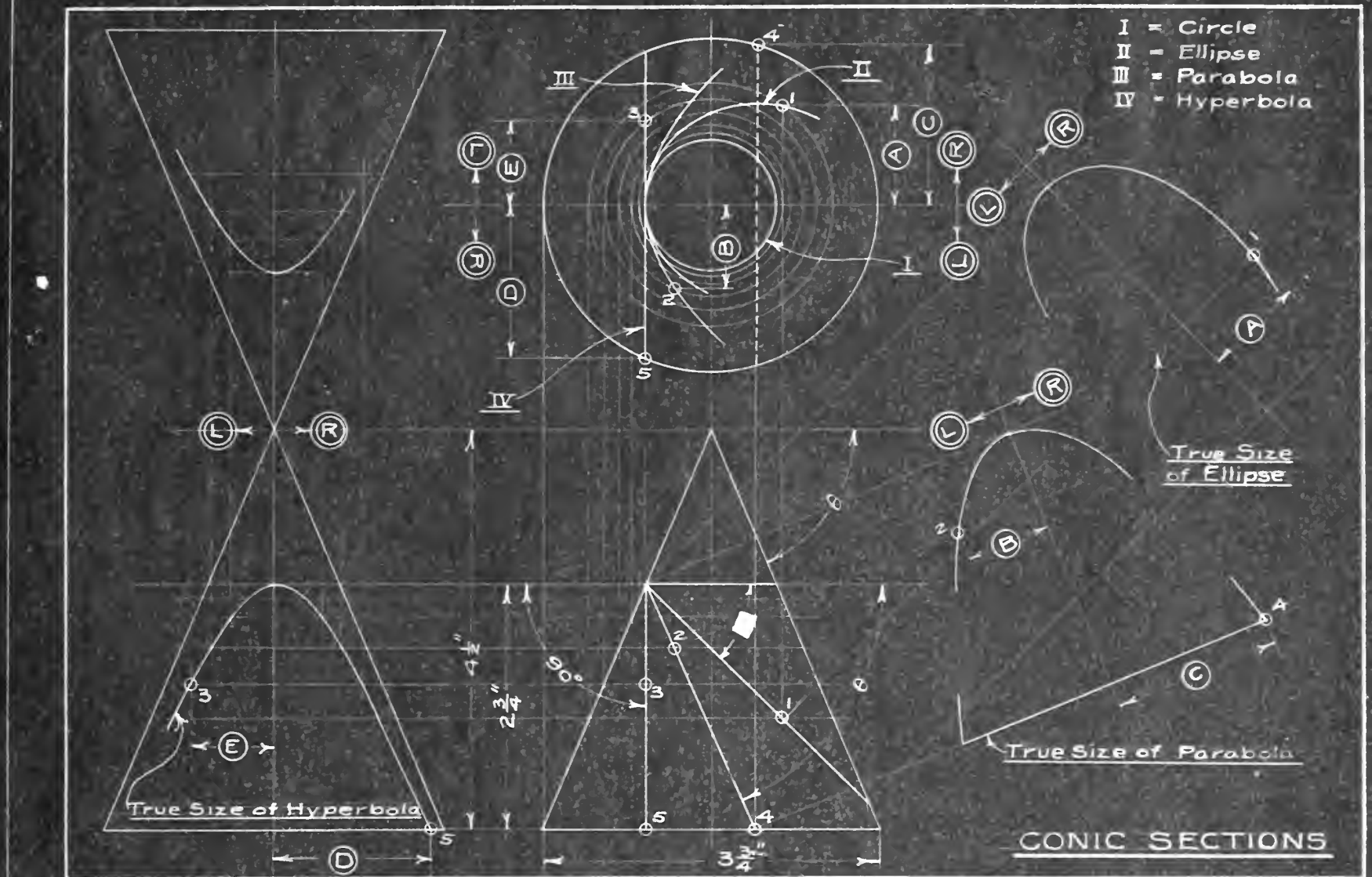
(*b*) The construction for finding the points where the Cutting Plane cuts through these lines and joining these points for the required curve follows the method of Sheet 12.

The points are first found in **F. V.** (see note at bottom of PAGE 60), then identified in **T.V.** and in *true size*.

Questions for Consideration

(1) Could the method of Sheet 12 be applied to the solution of this sheet, and *vice versa?*

(2) What are the advantages and disadvantages of each method?



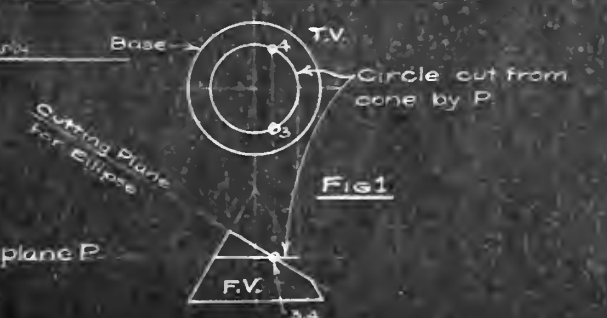


Fig 1

Fig 2

Sheet 13

SHEET 14

INTERSECTION OF CONE AND HEXAGONAL PRISM—NUT FOR BOLT

LECTURE DATE.....

SHEET 14

INTERSECTION OF CONE AND HEXAGONAL PRISM—NUT FOR BOLT

DIRECTIONS

I. Method of construction indicated on blue print. (As in *Conic Section* sheet we use *horizontal* Auxiliary Planes.)

Roman Numerals show *order* of construction.

(*a*) Make **Complete Top View.** (See Page 19. Ex. 1 for construction of hexagon.)

(*b*) Procedure as hitherto.

(*c*) Explain construction for some Auxiliary Plane other than the one given.

II. When completed and **approved** this sheet is to be *traced*.

(*a*) Use **Shade Lines*** on all views, in accordance with principles given on Page *115* (*on Tracing only.*)

(*b*) Omit all *Construction Lines* and *Explanation of Construction* on the Tracing.

(*c*) Put in Dimension and Centre Lines (*Red-light*).

(*d*) Arrows, Figures, and Lettering (*Black*).

* It is more convenient to draw first all unshaded lines; then open pen a little and draw all shaded lines.

NOTES

A. The curve developed on the *Front Face* is evidently a portion of an **Hyperbola**.

The same curve appears on the slanting faces, in both front and side views, but in both cases more or less foreshortened.

B. Nuts thus cut off by a Cone are said to be "**chamfered.**"

C. **F.V.** shows the nut "across corners."
R.V. " " " "across flats."

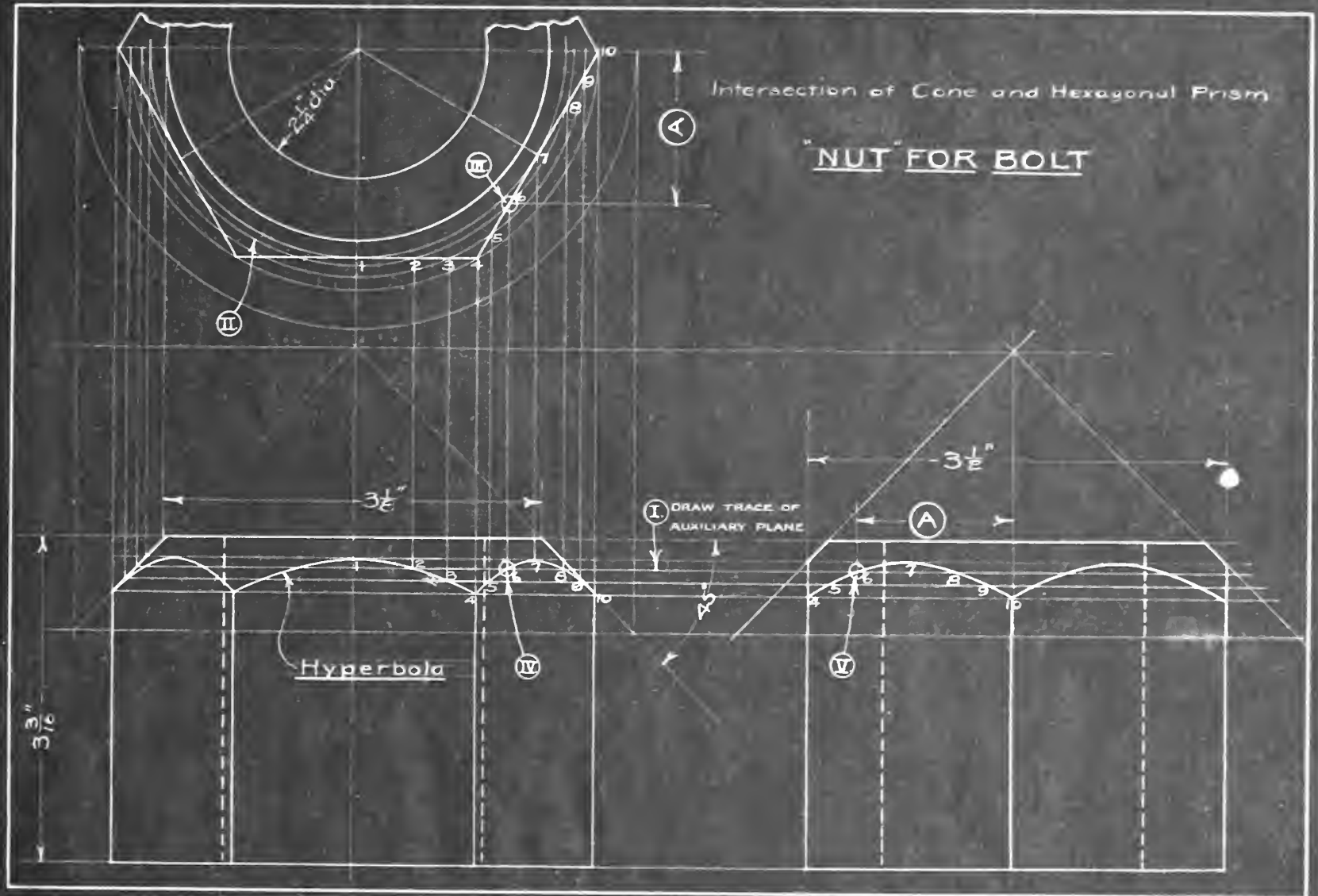
Questions for Consideration

(1) Sometimes the nut is cut off at the level of the tops of the curves. How does that change the 3 views?

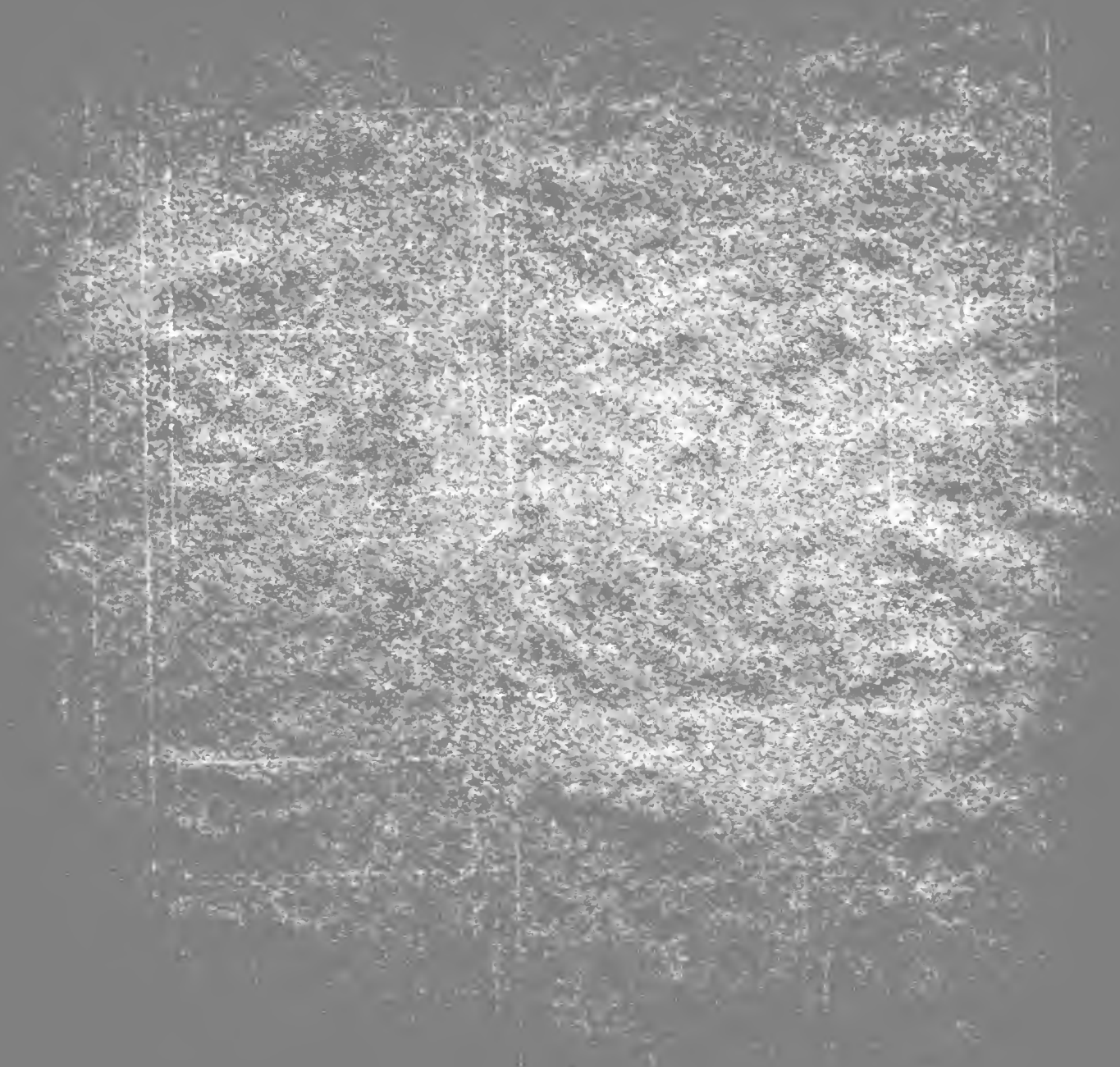
(2) Suppose, instead of being hexagonal, a nut were square (see Page 119–V), what would the resulting curves be?

(3) If, instead of being chamfered, a nut were "rounded" (*i. e.* Cone is replaced by Sphere), what would the resulting curves be?

(4) How would you construct the curves of 2 and 3?



NOTE: Roman numerals show order of construction.



LECTURE DATE.....

SHEET 15

INTERSECTION AND DEVELOPMENT OF PENTAGONAL AND TRIANGULAR PRISMS

DIRECTIONS

I. (*a*) Block out the 3 Views each of the Pentagonal and Triangular Prisms (both Equilateral).

Use identifying numbers for corners of the object.

(*b*) Work out Projection of *Intersection*.

(*c*) Work out Developments as indicated.

II. Procedure as hitherto.

III. Explain Construction.

(*a*) Indicate how you located a Reference Point in each Development. Measure Reference Distances from some chosen "datum edge" and from base of prisms.

(*b*) Substitute for "?" in Developments the proper dimensions taken from the corresponding lengths in the original views.

IV. Reproduce Developments on piece of Duplex Paper; cut out and fold to produce original subject.

NOTES

A. As on Sheet 11 the purpose of Development is to obtain *Patterns* which, when cut and properly folded, will produce the original subject drawn.

B. Method of constructing Intersection.

(*a*) In turn consider each *edge* of one prism as intersected by a plane of the other.

(*b*) Such an intersection is located first in a view where the plane is seen "edgewise" as a line. (See note at bottom of PAGE 60.)

(*c*) In **T.V.** an edge of the Triangular Prism starts from **7** and is intercepted at **10** by a plane of the Pentagonal Prism.

(*d*) Now the **F.V.** of this edge must be the same length, *i.e.* **7–10.** We can, therefore, locate point **10** in **F.V.**

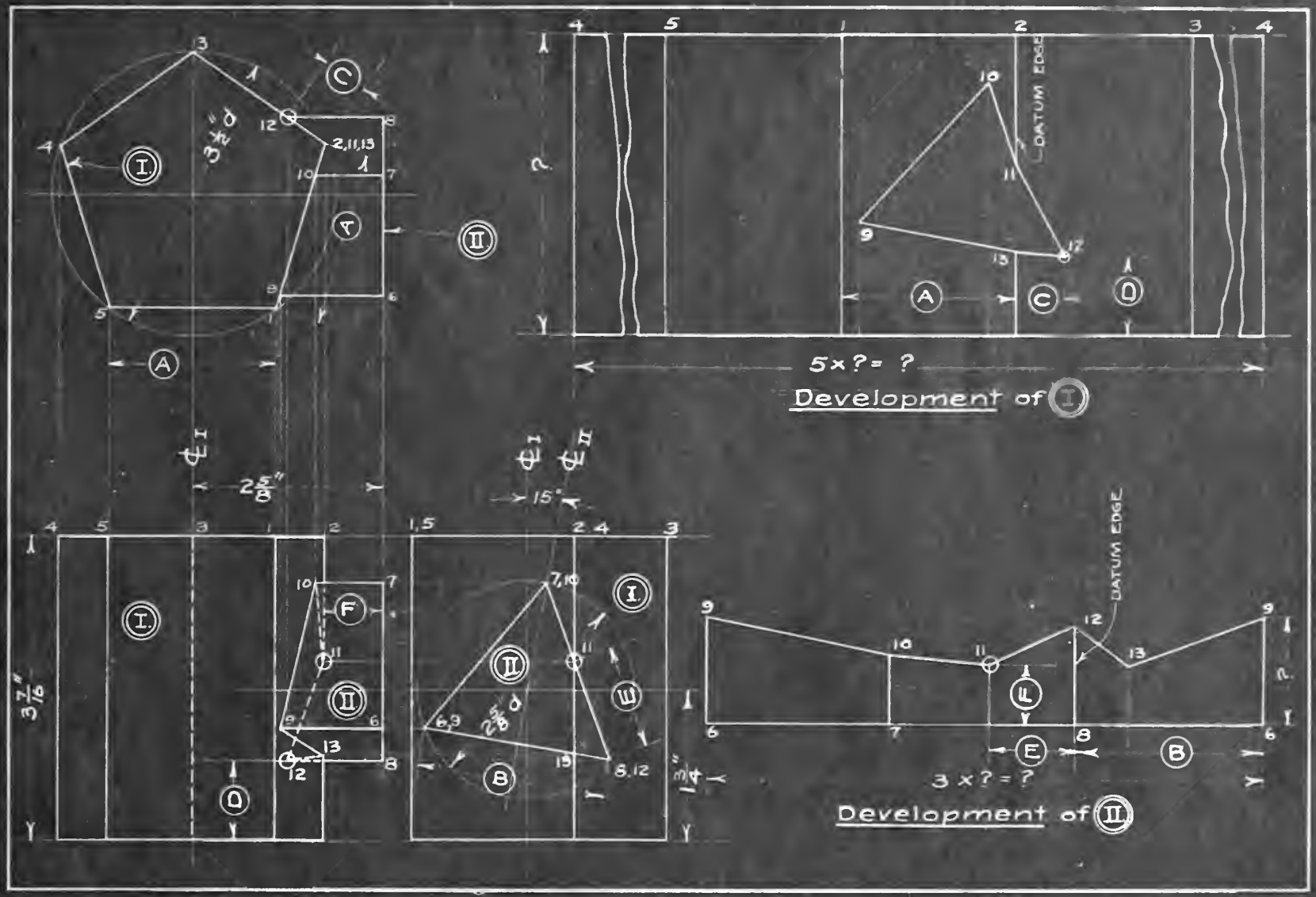
(*e*) Similarly for other points of intersection.

Questions for Consideration

(1) Under what assumption is the line **11–13** in **R.V.** full?

(2) " " " could it properly be dotted?

(3) Suppose the triangular prism were inclined (say 30° to the horizontal), how would you find the intersection?


DATUM EDGE
5x?= ?
Development of I
DATUM EDGE
3 x ? = ?
Development of II

LECTURE DATE.....

DIRECTIONS

I. (*a*) Block out 3 views of Large Cylinder (**I**).

Use identifying numbers and letters on all points as suggested.

(*b*) Block out **F. V.** and **E. V.** of Small Cylinder (**II**).

(*c*) Work out **T. V.** and **R. V.** of (**II**).

In stepping off arcs use *very small* intervals. (See PAGE 35–FIG. 2.)

(*d*) Work out Projection of Intersection.

(*e*) Draw Developments.

In Development of II cut cylinder at some other point than that shown on blue print.

II. Dimensions "?" are to be supplied by scaling the drawing.

III. EXPLAIN CONSTRUCTION.

(*a*) In red ink draw the traces of some other Auxiliary Plane than the one given.

(*b*) Identify (in all views and developments) the point which that plane gives, measuring from some chosen "datum element."

NOTES

A. Method of Construction.

(*a*) A *vertical* Auxiliary Plane parallel to axis of the small cylinder (as shown by its trace, **12–m–h, R. V.**) will cut a line (**12–m–z**) on the surface of the small cylinder in **T. V.** (identified by distance **A**).

(*b*) It will also cut the line (**12–z**) in **F. V.**

(*c*) Having identified the views of this line or *Element* of the cylinder, we proceed with the construction precisely as if the element were the edge of a prism, following the method of Sheet 15.

(*d*) In **T. V.** the element is intercepted at **m** by surface of Large Cylinder; by projecting down, therefore, we identify point **m** in **F. V.** This gives one point in this curve of intersection. The others can be found similarly, and curve drawn.

The Auxiliary Plane would also cut surface of small cyclinder on *under side*. Each plane, therefore, will give two points of intersection.

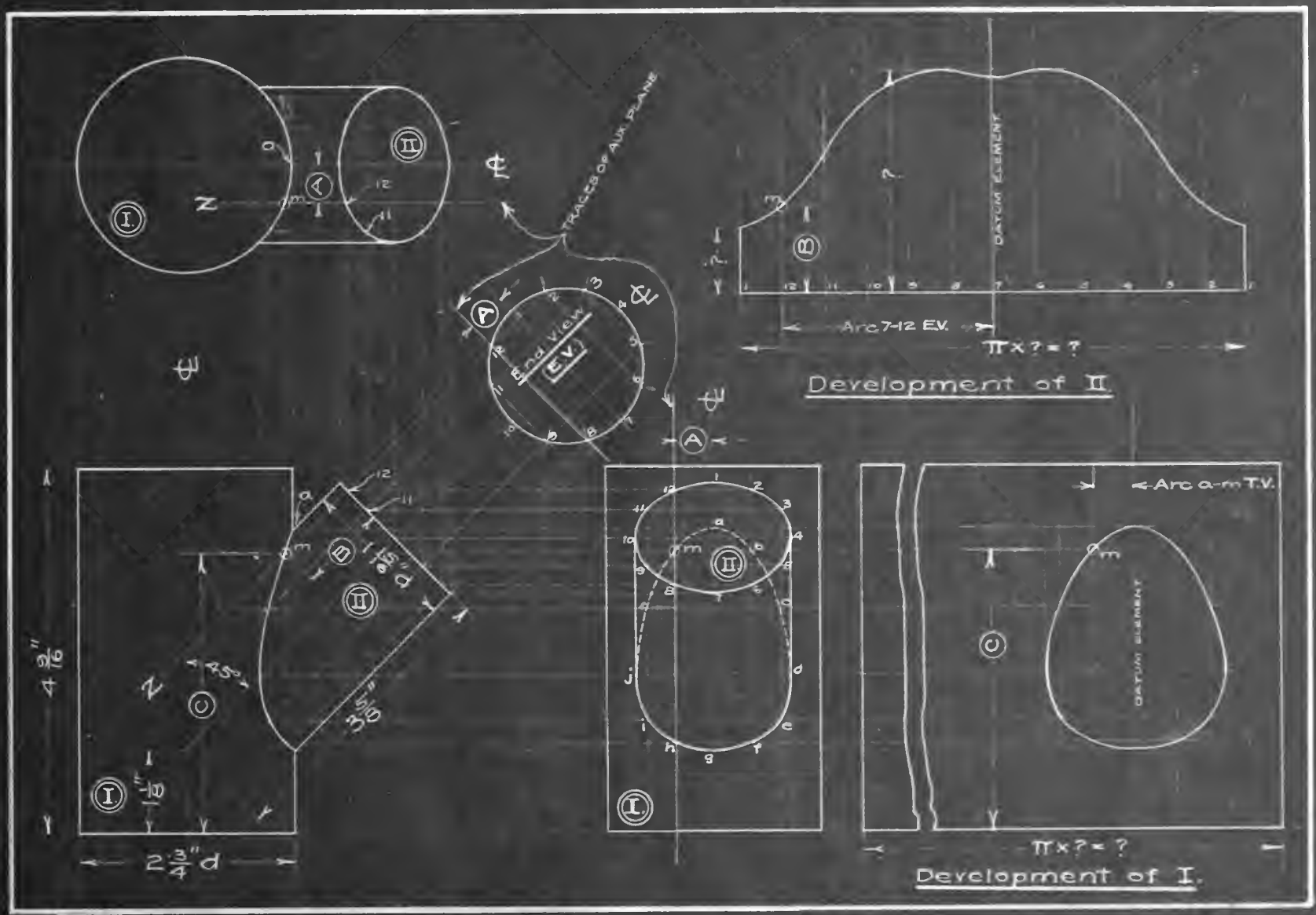
B. Auxiliary Planes can be taken at will, but for convenience in development it is best to make arcs **1–2**, **2–3**, etc., on **E. V.** all *equal*.

In laying out Development of **II** take length of circumference and divide into proper number of parts.

Questions for Consideration

(1) If two cyclinders of equal diameter (axes crossing at angle of 90°) intersect, what do **F. V.** and **R. V.** of intersection become?

(2) Given cylinder (II) as shown, but a square *prism* instead of cylinder (I). What are the 3 views of the curve of intersection?


TRACES OF AUX. PLANE
End View
E.V.
DATUM ELEMENT
Arc 7-12 E.V.
πx ? = ?
Development of II
Arc a-m T.V.
DATUM ELEMENT
πx ? = ?
Development of I.
2 3/4" d
4 3/16"
3 5/16"
1 5/16" d
45°

LECTURE DATE.....

DIRECTIONS

I. Draw first the *Orthographic Views.*

Note that the scale is **4** inches = **1** foot.

II. Develop the *Isometric Drawing* from the Orthographic Views. Start with Point **1**, and build up the figure by locating *successive points* (method indicated by reference distances) and then join the points by the required straight or curved lines.

When small curves cannot be conveniently drawn with the French Curve, a radius can often be found to approximate the required curve, and compasses can be used.

III. Explain Construction.

Show Point **1** as on blue print. Then locate at least 3 selected Reference Points other than those given, and indicate, by Reference Distances, correspondence between Orthographic Views and Isometric Drawing.

IV. When completed and approved the sheet is to be *traced.*

On the tracing: —

(*a*) Omit all construction lines and all Explanation of Construction.

(*b*) In Isometric Drawing omit also all *axes.*

(*c*) Put in dimensions and lettering.

(*d*) Use method of inking given for previous tracings.

NOTES

A. **Isometric Drawing*** is a method of showing, in one View, what in *Orthographic Projection* requires two or more views. It resembles a distorted *Perspective Drawing.*

B. Briefly, in Orthographic Projection we have 3 axes which can be called *Width* (**W**), *Depth* (**D**), and *Height* (**H**), respectively.

In Isometric Drawing these are all combined in one View by imagining an object tipped at an angle. This tipping is such as to make the **W** and **D** axes each form an angle of **30°** with the *horizontal*, while the **H** axis remains *vertical.*

Any distance parallel to any one of the 3 axes in Orthographic Projection is then laid off in the Isometric Drawing in its *true length* parallel to the corresponding axis.

By joining points thus located we develop an Isometric View.

C. It follows from above that *only those lines which are parallel to any one of the 3 axes* are shown in their *true length* in an Isometric View.

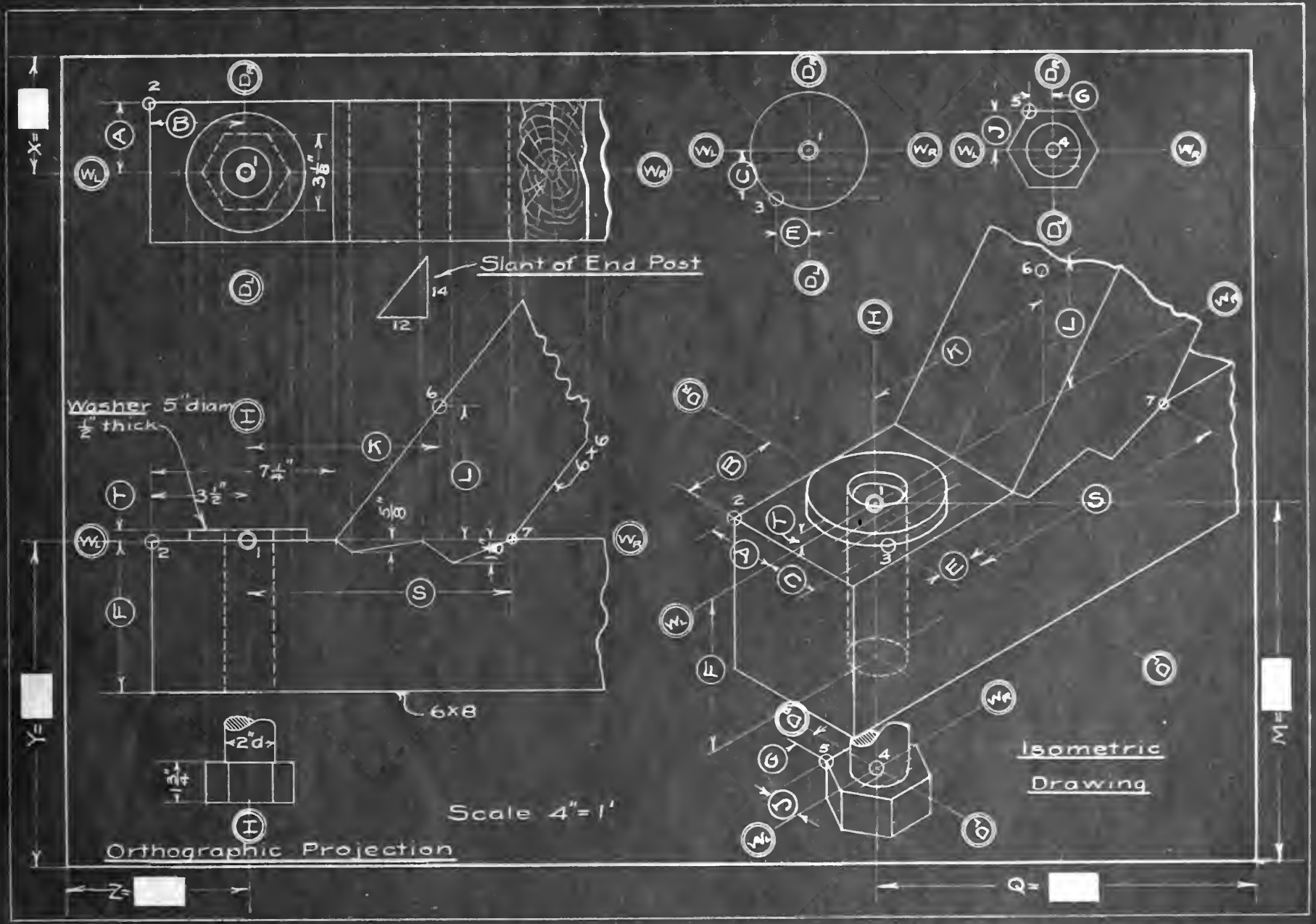
D. The subject of this sheet is the "End Post" joint of a timber Roof or Bridge Truss.

Question for Consideration

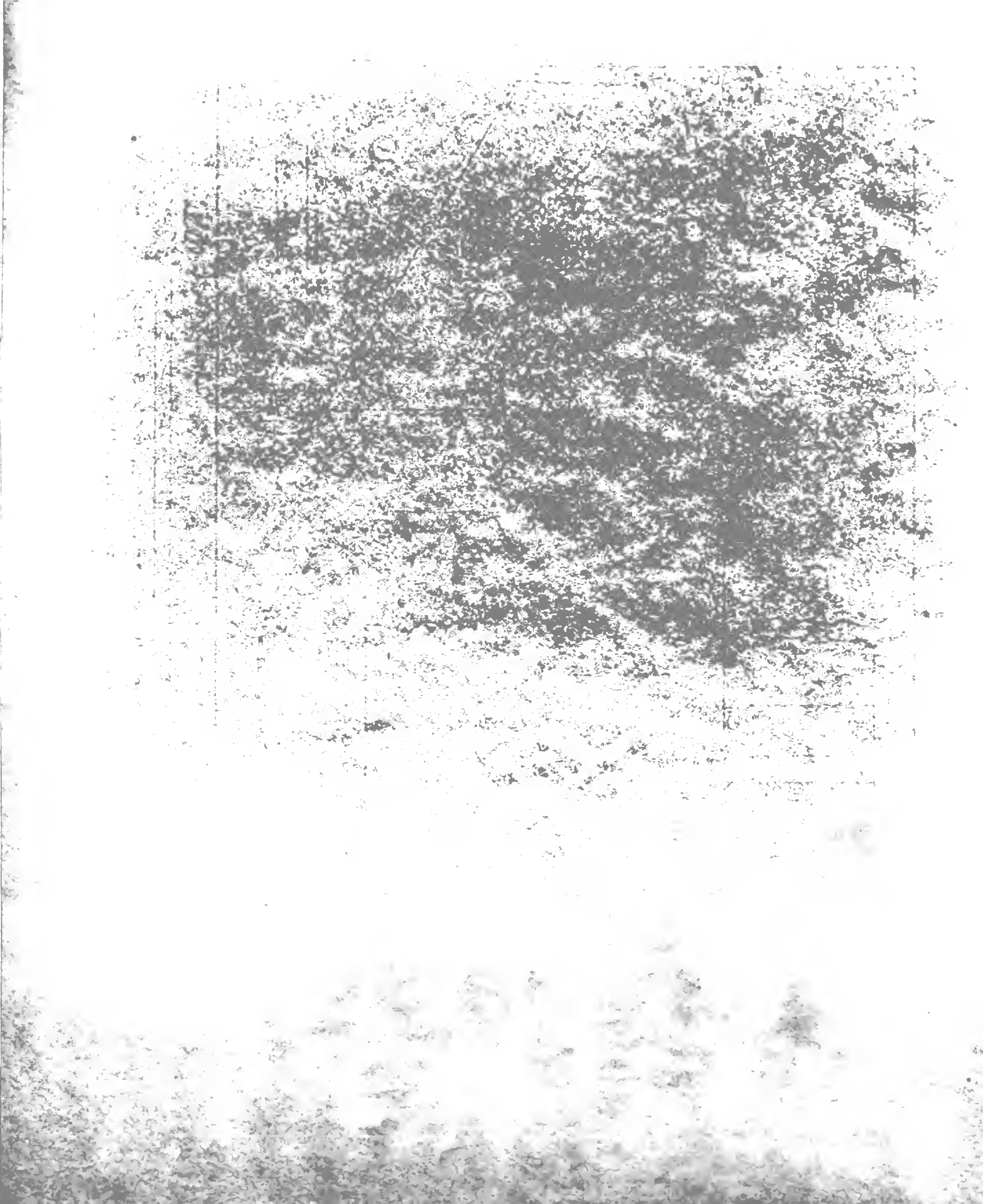
(1) What lines, if any, appear in the Isometric Drawing *longer* than their real length?

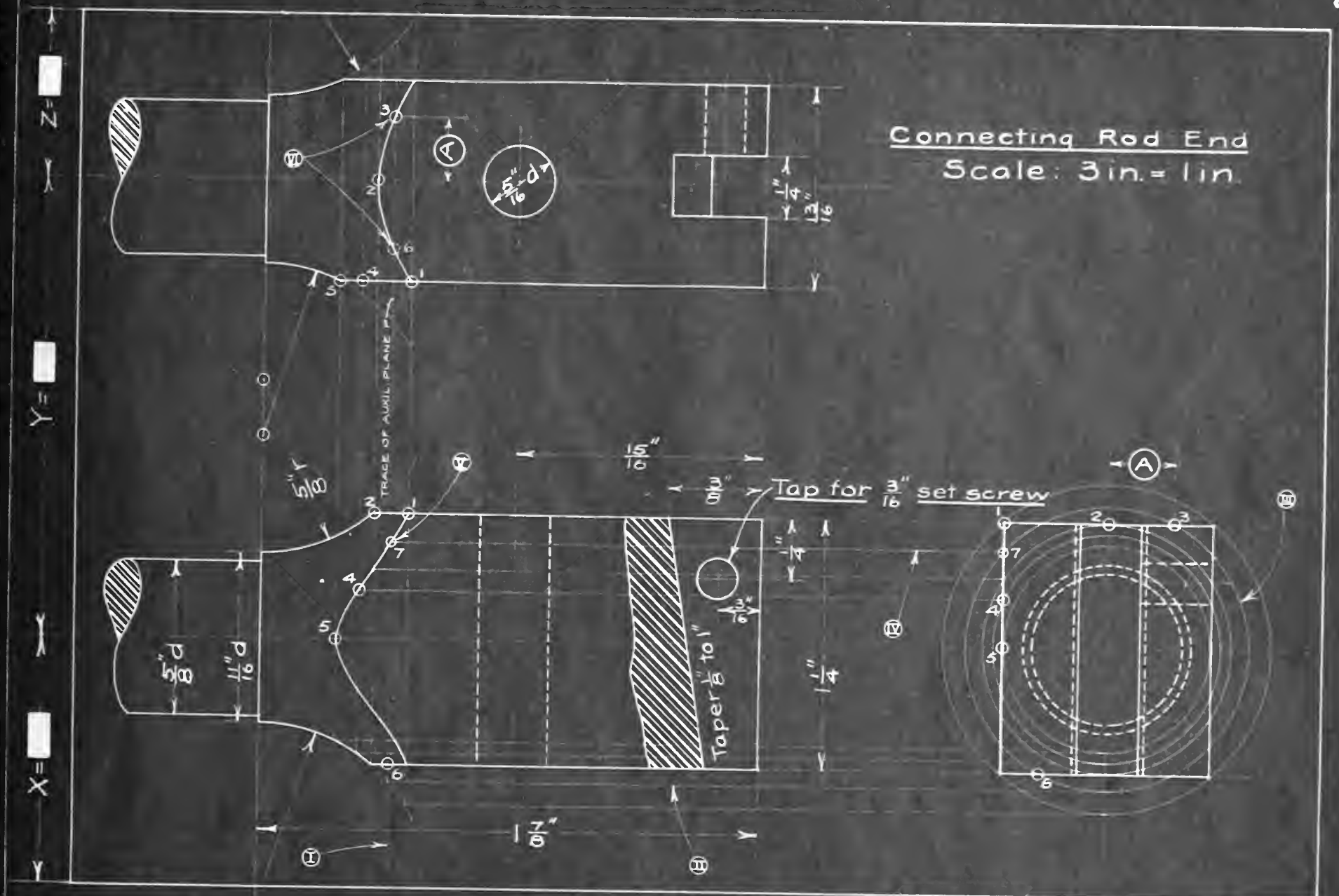
(2) If so, how do you explain the fact?

* A distinction must be noted between the above described Isometric "*Drawing*" and strict Isometric "*Projection.*" In the latter the lengths of all lines parallel to any one of the axes would be 0.8165 times their true length. In practice, however, this correction is rarely made, and the true lengths instead of the corrected ones are used as above described.



Note: Timber sizes are stated thus: 2×4 (2"×4"), 6×6, 6×8 etc.
In this exercise draw a 6×8 (8" side vertical)





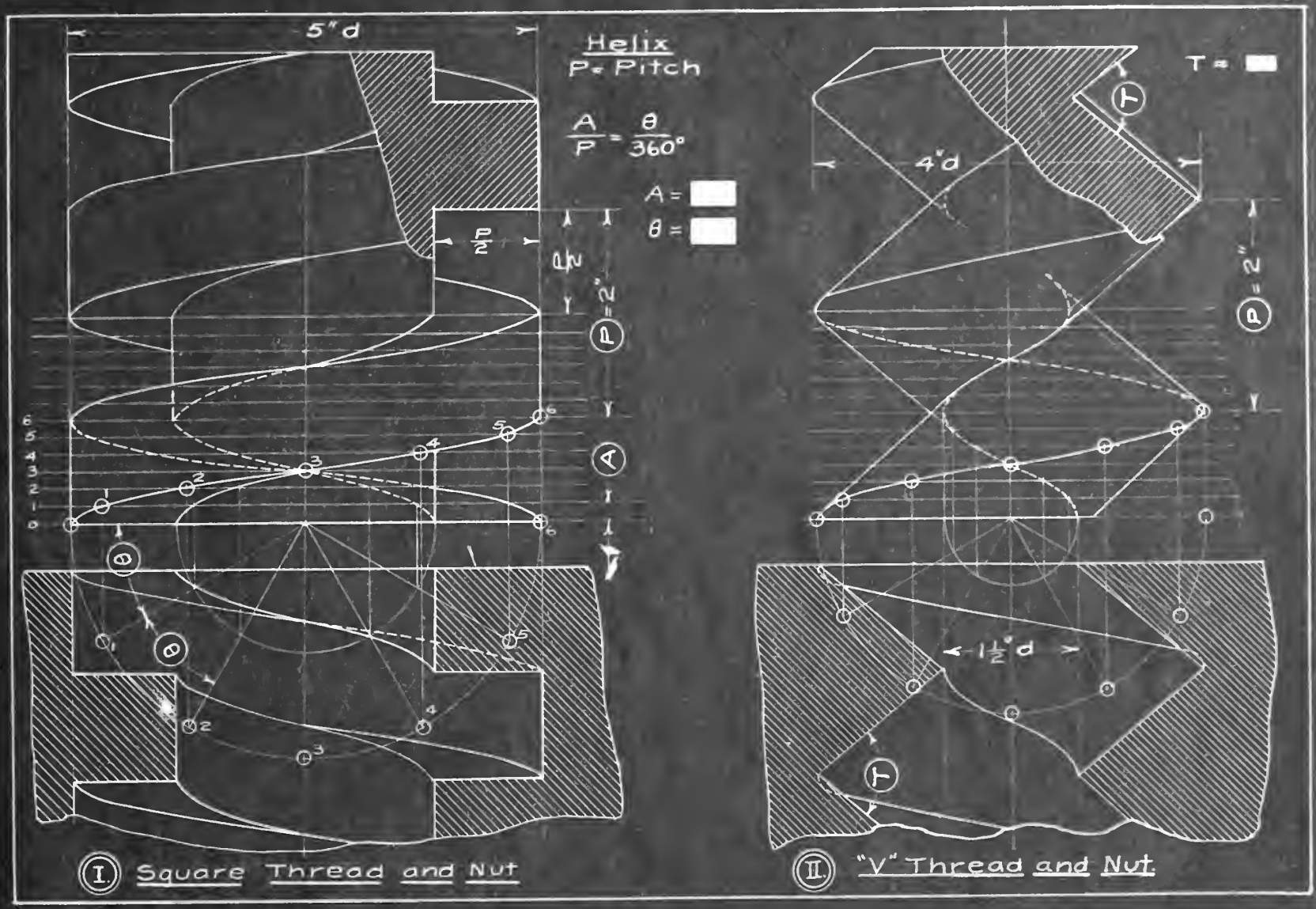
(1) Use Auxiliary planes perpendicular to axis of rod. (Plane P for example)

(2) I, II, III, etc. show order of construction for plane P

(3) On your sheet, explain const similarly for another plane.

Sheet 18

ON YOUR SHEET SHOW SECTION ON LEFT SIDE OF ℄ INSTEAD OF RIGHT.



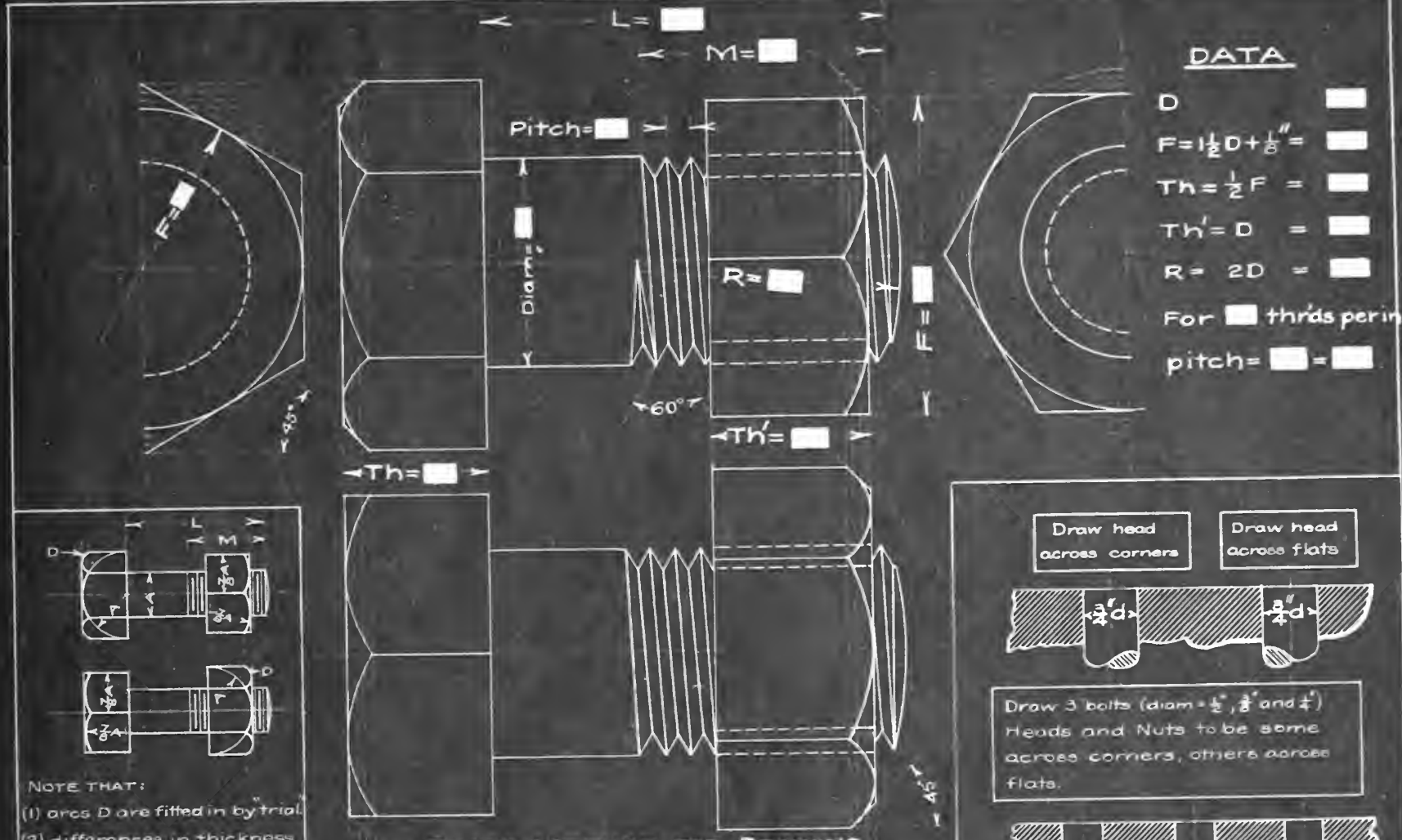
(I.) (1) (θ) = some convenient divisor of 360° - make it to give at least 8 points in semi-circumference.

(2) Make (A) to correspond (3) Record values of (A) and (θ) selected.

(II.) (1) (T) = "angle of thread" In this case scale off T with protractor and record above.

(2) For standard threads (T) usually equals 60° [See page 119]

Sheet 19



NOTE: (a) "Exact" method shows proportions as the bolt and nut are actually made in the shop according to a common standard in practice

(b) "Conventional" method is a shorthand way of drawing same bolt and nut.

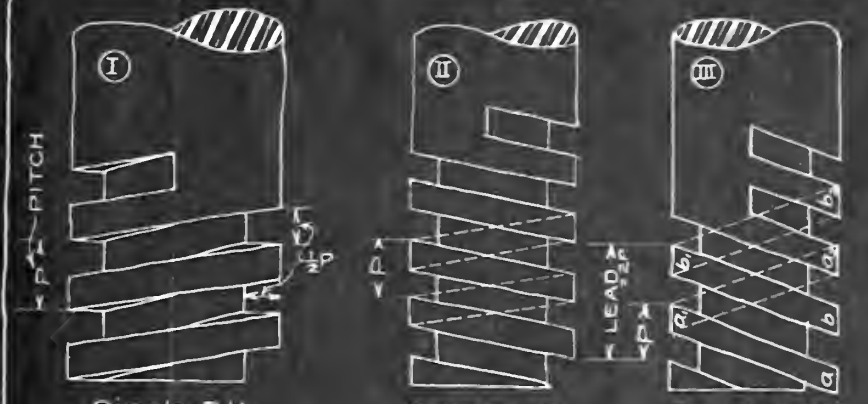
(c) For no. of threads per inch – standard for given diam. – see page 119.

(d) To define a standard bolt, only 3 dimen. are needed-diam, length, dist. threaded.

Stage 1 - Block Out
Stage 2 - Complete all drawings
} Black Pencil

Stage 3 - Dimen Lines - Red Pencil
Stage 4 - Lettering - Black Pencil

CONVENTIONAL METHOD FOR DRAWING SQUARE THREADS



I — Single R.H. Diam= ■ Pitch= ■ — Slightly Conventionized — For large threads.

II — Single L.H. Diam= ■ P= ■ — Extreme Convention — Dotted Lines unnecessary

III — Double L.H. Diam= ■ P= ■

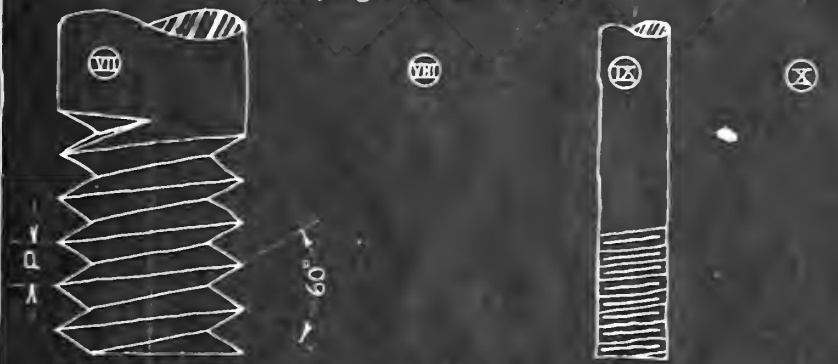
IV — Single L.H. Diam= ■ P= ■

V — Double R.H. Diam= ■ P= ■ Lead= 2P

VI — Triple R.H. Diam= ■ P= ■ Lead= 3P

CONVENTIONAL METHOD FOR DRAWING "V" THREADS

See page 119-VII-note.



VII — Single R.H. Diam= ■ P= ■ — Slightly Conventionalized — For large threads

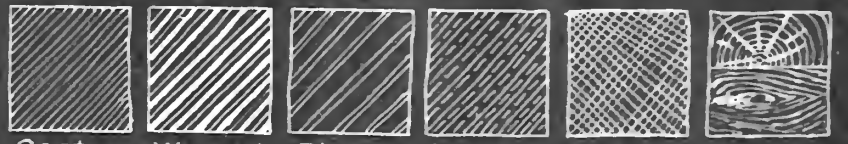
VIII — Single L.H. Diam= ■ P= ■

IX — R.H. Diam= ■ — Extreme Convention — For small threads

X — L.H.

CONVENTIONAL CROSS HATCHINGS

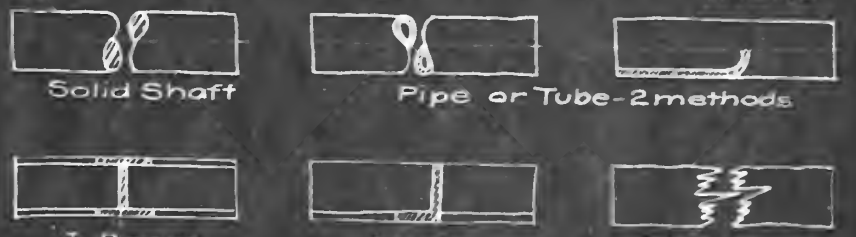
For other cross hatchings see page 115.



Cast Iron | Wrought Iron | Steel | Brass | Babbit, Lead, etc. | Wood

XI

CONVENTIONAL BREAKS AND TURNED SECTIONS



Solid Shaft — Pipe or Tube - 2 methods

I Beam — Angle — Timber

XII

NOTE: R.H. = Right Hand L.H. = Left Hand

In III notice that a, a_1, a_2 is one distinct threads and b, b_1, b_2 is another, quite independent of the first.

"Lead" or "pitch of each thread" = 2 P for double thread
= 3 P for triple thread, etc.

III shows liberty taken with section view of spoke

IV shows different ways to draw sections

V shows all necessary dimensions in one view

I

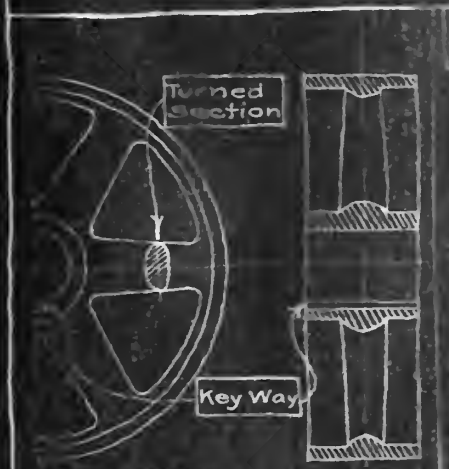
V shows (a) several parts drawn together

(b) section on given line with shaft unsectioned

(c) drilled holes - size and location

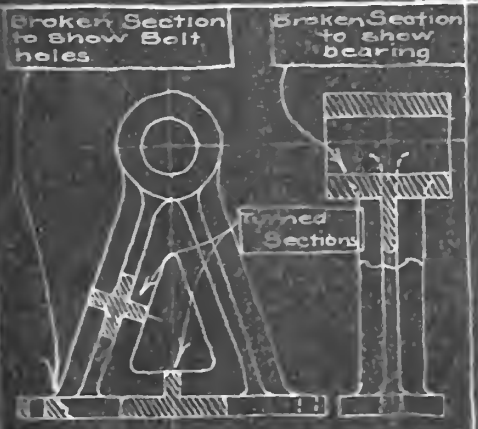
(d) surfaces to be machined by 'f'

II



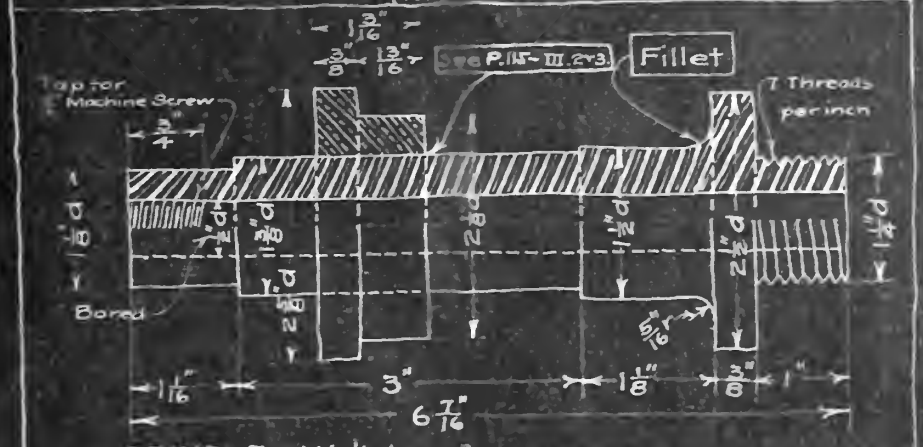
FLY WHEEL or PULLEY

III

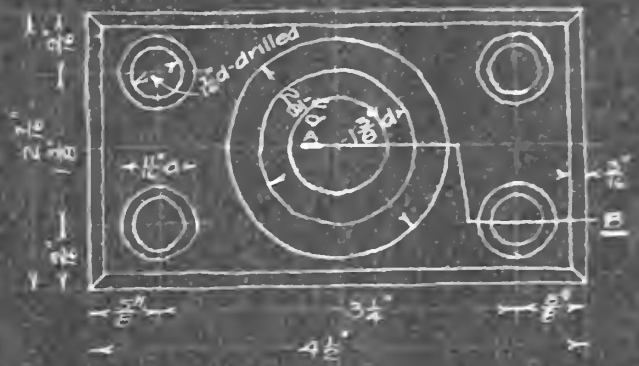


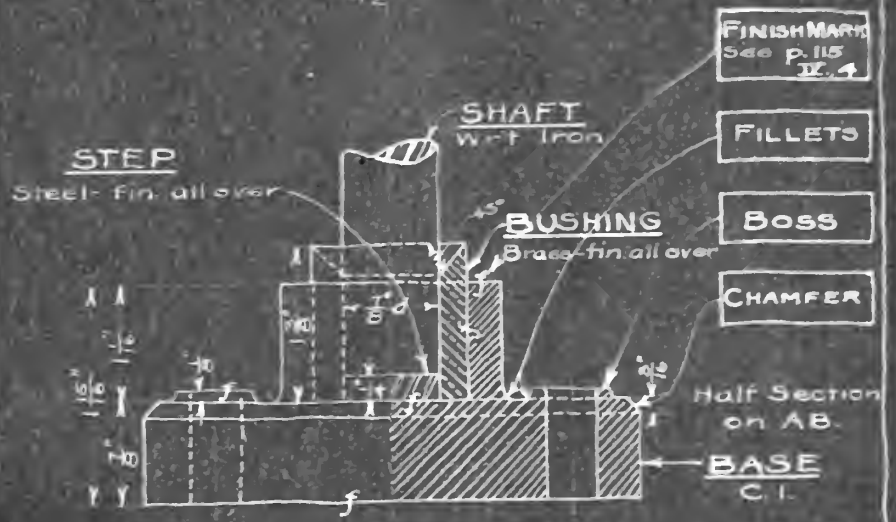
PEDESTAL BEARING

IV



V





STEP BEARING

Scale: Full Size

One of this complete

Title here

VI

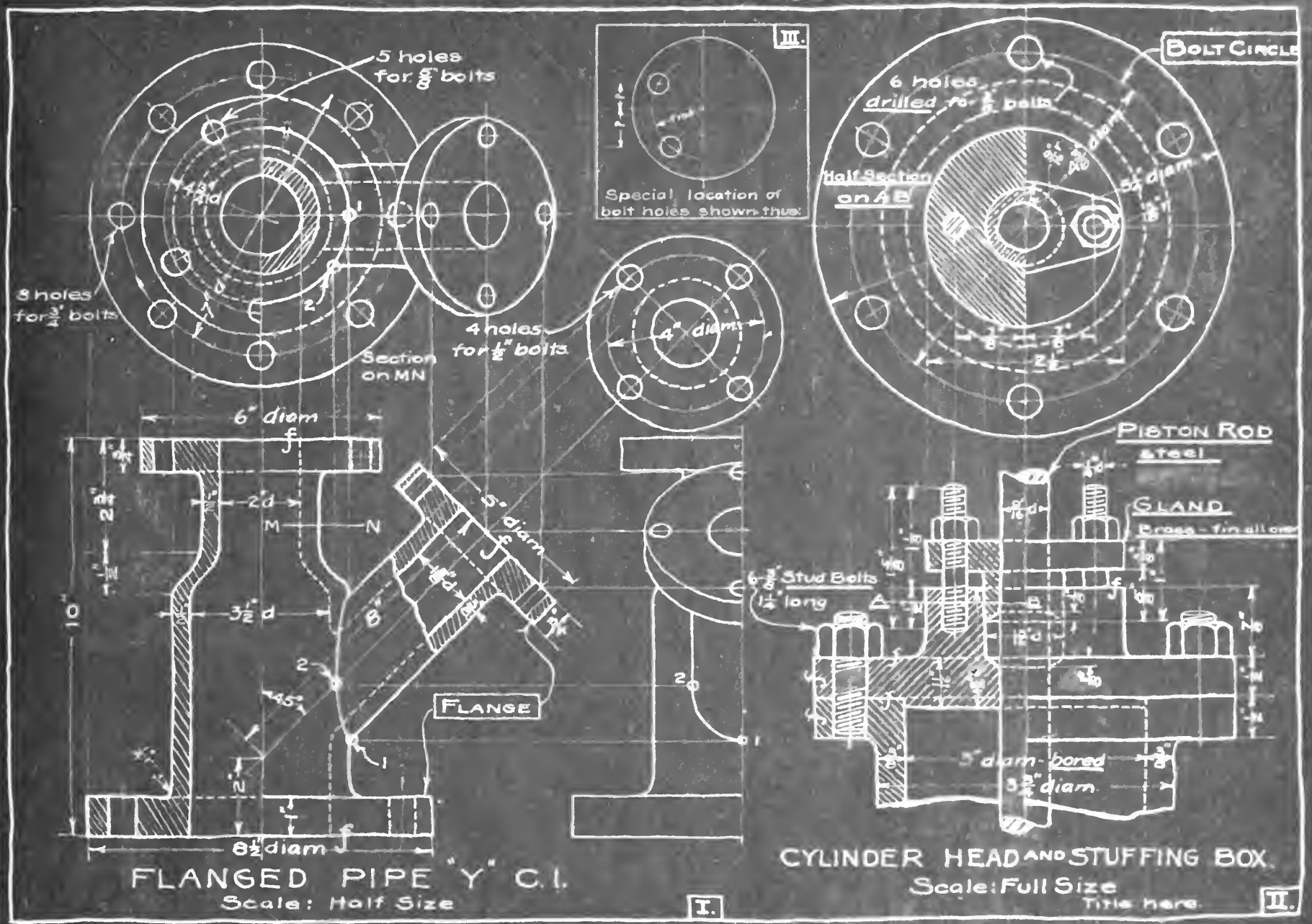
(1) This sheet to be drawn FREE HAND on Sketching Pad

(2) By 4 stages as on sheet 21

(3) Check carefully for errors in dimensions.

SOME DRAFTING CONVENTIONS

Sheet 22.



NOTE: This sheet shows,
(1) Method of defining Bolt Holes (I→II)
(2) Liberty taken with Projection of Bolt Holes (I→II)
(3) Method of "HALF SECTION" with Rod and Bolts in place (II).

SHEET 24—PREPARATION OF A WORKING DRAWING

SUBJECT—ENGINE CRANK

LECTURE DATE.....

SHEET 24 — PREPARATION OF A WORKING DRAWING

SUBJECT — ENGINE CRANK

DIRECTIONS

I. **Freehand Sketch** (Sheet 24–*a*).

(*a*) Crank is to be drawn carefully FREEHAND on Sketching Pad.

(*b*) Draw directly from the object, obtaining proportions BY EYE ALONE.

(*c*) Follow stages.

1. Block out. (See notes **A** and **B**.)
2. Complete drawing. (Then correct your drawing by comparing with large blue print in drawing room.)
3. Draw dimension lines (*Red pencil*). Follow III on PAGE 97.
4. With black pencil put in

   Dimension figures. (Measuring Crank with rule and calipers.)

   Bill of Material. (See II on PAGE 97.)

II. **Pencil Drawing** (Sheet 24–*b*).

(*a*) To be done with instrument on Duplex paper (12 × 18).

(*b*) Correct carefully but do not put check marks on this sheet. Sheets will be exchanged and checked later when notice is given.

III. **Tracing** (Sheet 24–*c*).

NOTES

A. Choose your own set of views without consulting those given on PAGE 97. After choosing and blocking out views, submit to an instructor for discussion of merits of the choice.

B. **Choice and arrangement of views.**

1. Select for **Front View** one which gives clearest idea of object.
2. If possible place **F. V.** to show object in its *natural position*.
3. Draw as many other views as are necessary to show the object clearly.
4. Select views which show important lines *full* rather than *dotted*.

   NOTE. — Hidden lines (dotted) should be drawn only when they add to the general clearness of the drawing.
5. **Arrange all views** in accordance with the principles of Projection given on earlier sheets (*i.e.* **T. V.** above; B. V. below; R. V. at right; etc.). This is the usual practice in the United States.
6. To avoid confusion, hold object stationary and imagine your own standpoint changed for each view, instead of turning the object itself.

C. The **Bill of Material** (PAGE 97–II) is a list of all the parts with certain information about each one. The witness marks (first column), though not always shown, help to identify parts, especially when there are several nearly alike, or when a part has no commonly used name.

III is one of many possible arrangements - taken merely for illustration. It would perhaps be better to have axis of shaft horizontal in F.V. - its natural position on an engine.

IV shows 4 possible arrangements – all correct - 2 or 4 perhaps best - axis of shaft in natural position.

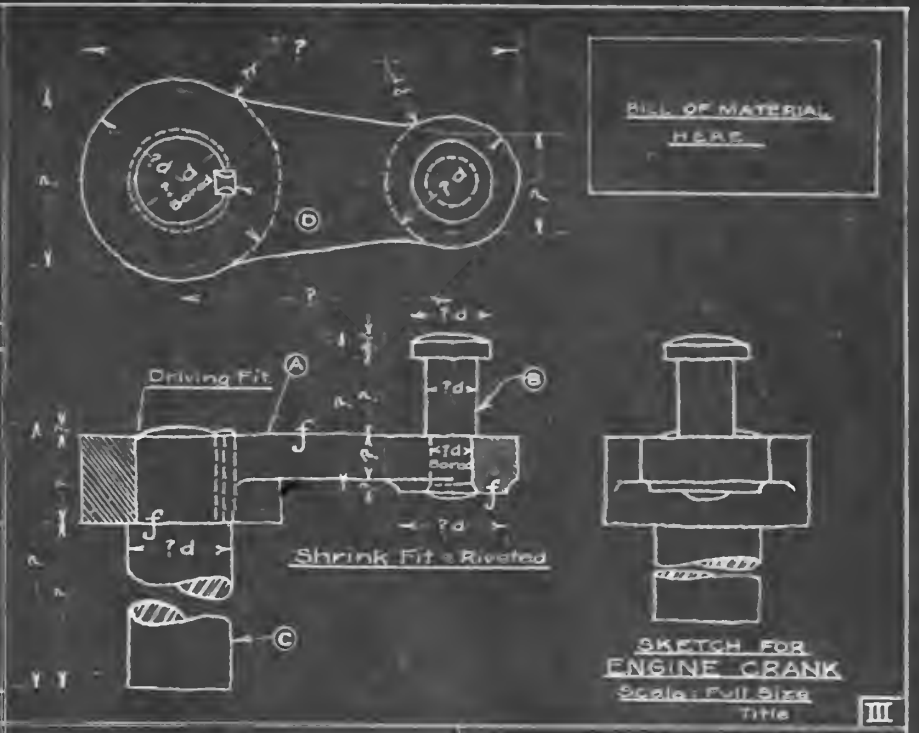
V shows 4 other arrangements, also correct but less satisfactory – too many important lines hidden.

I

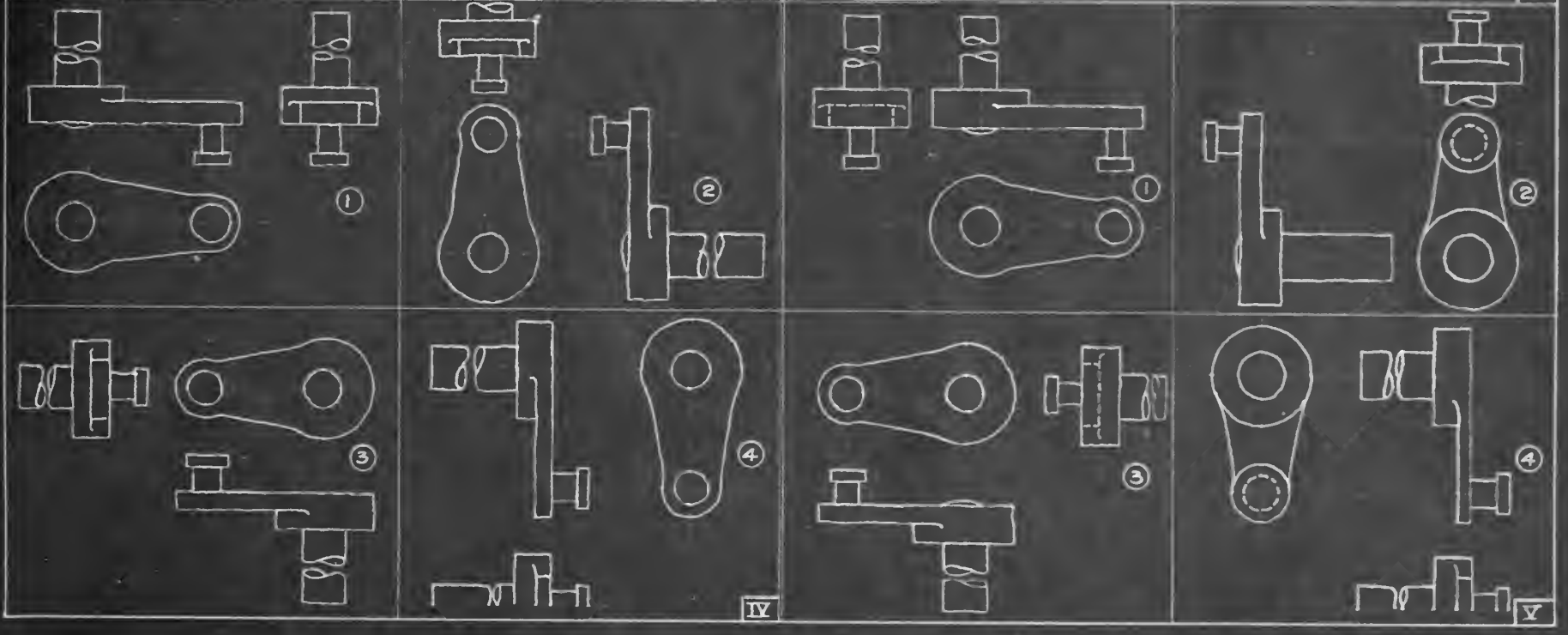
BILL OF MATERIAL

MARK	NO WANTED	NAME	MAT'L	REMARKS
A	1	Face	C.I.	
B	1	Pin	Steel	Finish all over
C	1	Shaft	W.I.	Finish all over
D	1	Pulley	Steel	$\frac{3}{8}'' \times \frac{3}{8}'' \times 1\frac{1}{4}''$

II



III



IV V

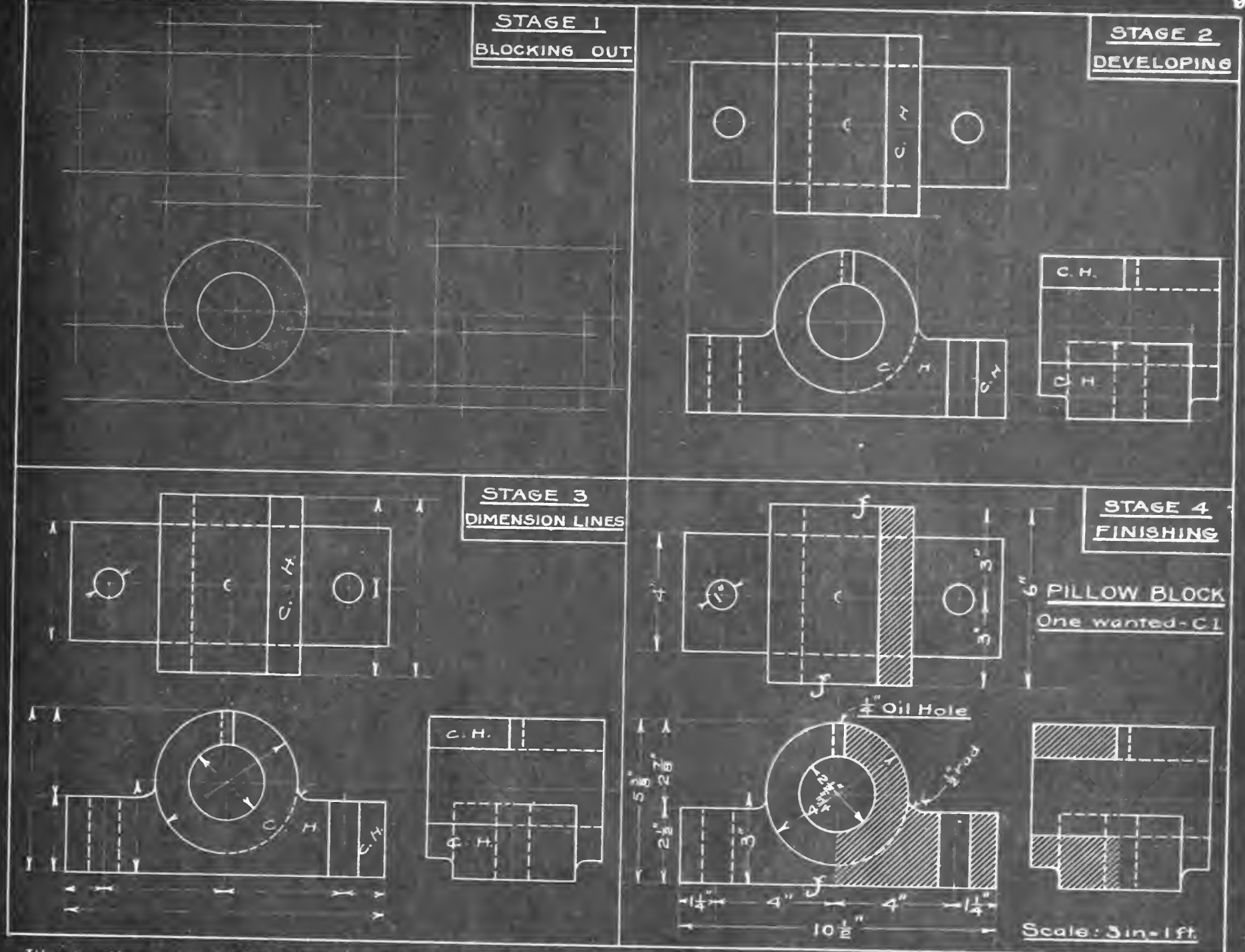


Illustration of 4 STAGES in PENCILLING

(4 stages in INKING see page 28)

Pillow Block = Bearing for Shaft or Journal.

SHEET 25

COUNTER SHAFT

I - Free-hand Sketches of Details.

II - Free-hand Layout.

This is to indicate arrangement and Location of views on the Pencil Sheet Represent, to scale, each view as a rectangle and draw location dimen's.

III - Pencil Drawing of Assembly.

On duplex paper - 18"x24" - 1" border inside

IV - Tracing.

V - Blue Print

BILL OF MATERIAL

MARK	NO WANTED	NAME	MAT'L	REMARKS
A	1	Frame	C.I.	
B	1	Cone Pulley	C.I.	with $\frac{3}{8}$"x$\frac{1}{2}$" Set Screw
C	1	Tight Pulley	C.I.	with $\frac{3}{8}$"x$\frac{5}{8}$" Set Screw
D	1	Loose Pulley	C.I.	with Oil Hole
E	1	Shifting Yoke	C.I.	
F	1	Shaft	Steel	Finished Bright
G	1	Shifter Rod	W.I.	
H	1	Spring	Brass	#13 Wire B&S
J	1	Bell Crank Lever	W.I.	J and K connected
K	1	Link	W.I.	by Rivet - W.I. $\frac{1}{4}$"x$\frac{23}{32}$"
L	1	Guide Plate	W.I.	
M	2	Guide Plate Screws	W.I.	(each as detailed.
N	1	Yoke Bolt	W.I.	

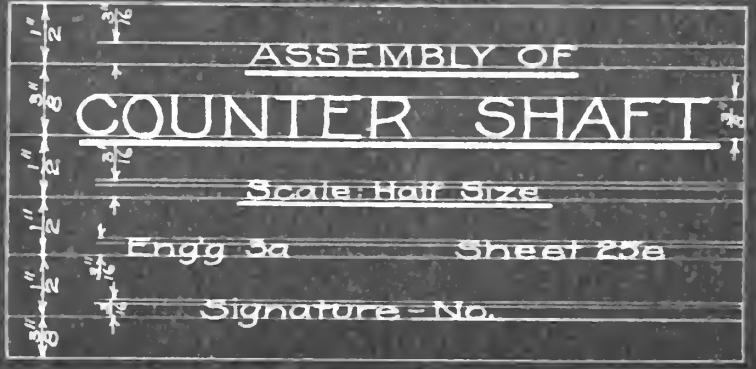
In Spacing Lines see page 113-2

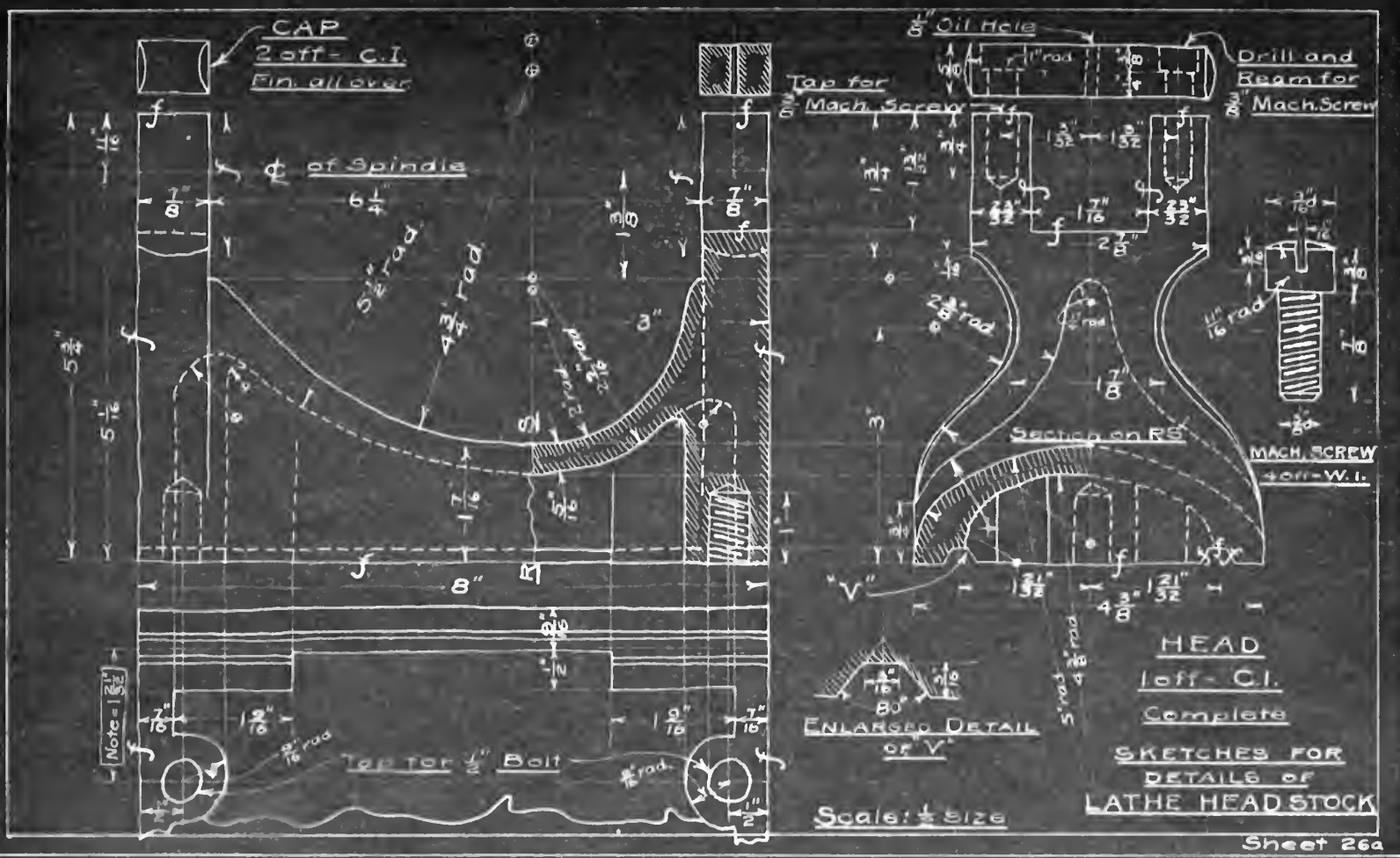
BOLT AND SCREW LIST

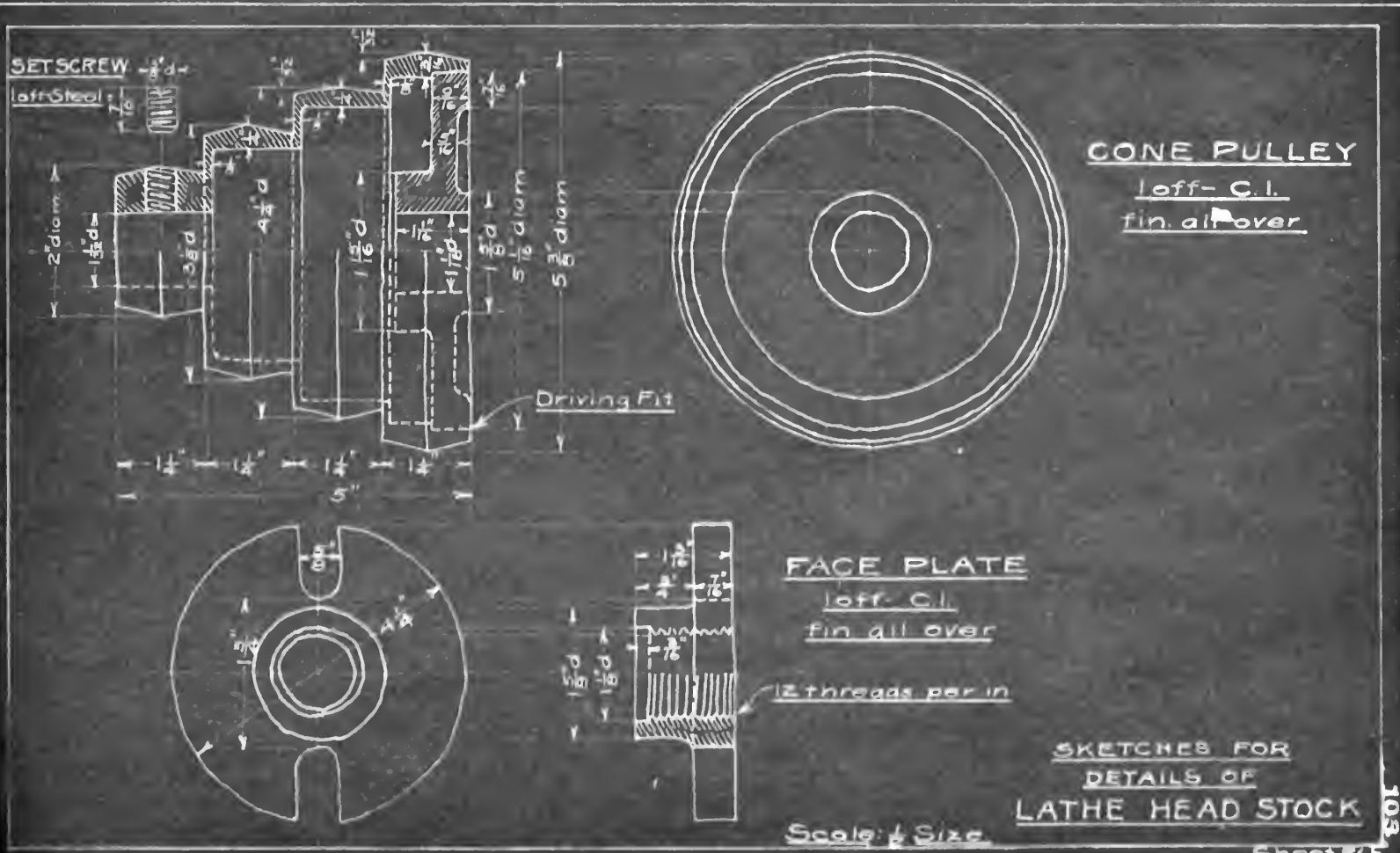
NO. WANTED	DESCRIPTION	MAT'L	FOR
1	$\frac{3}{8}$"x$\frac{1}{2}$" Set Screw	Steel	Cone Pulley
1	$\frac{3}{8}$"x$\frac{5}{8}$" Set Screw	Steel	Tight Pulley
1	$\frac{1}{4}$"x$\frac{23}{32}$" Rivet	W.I.	Link
1	$\frac{3}{8}$"x1$\frac{3}{16}$" Cap Screw	W.I.	Guide Plate
1	$\frac{3}{8}$"x$\frac{11}{16}$" Cap Screw	W.I.	Guide Plate
1	$\frac{3}{8}$"x1$\frac{3}{16}$ Bolt	W.I.	Yoke.

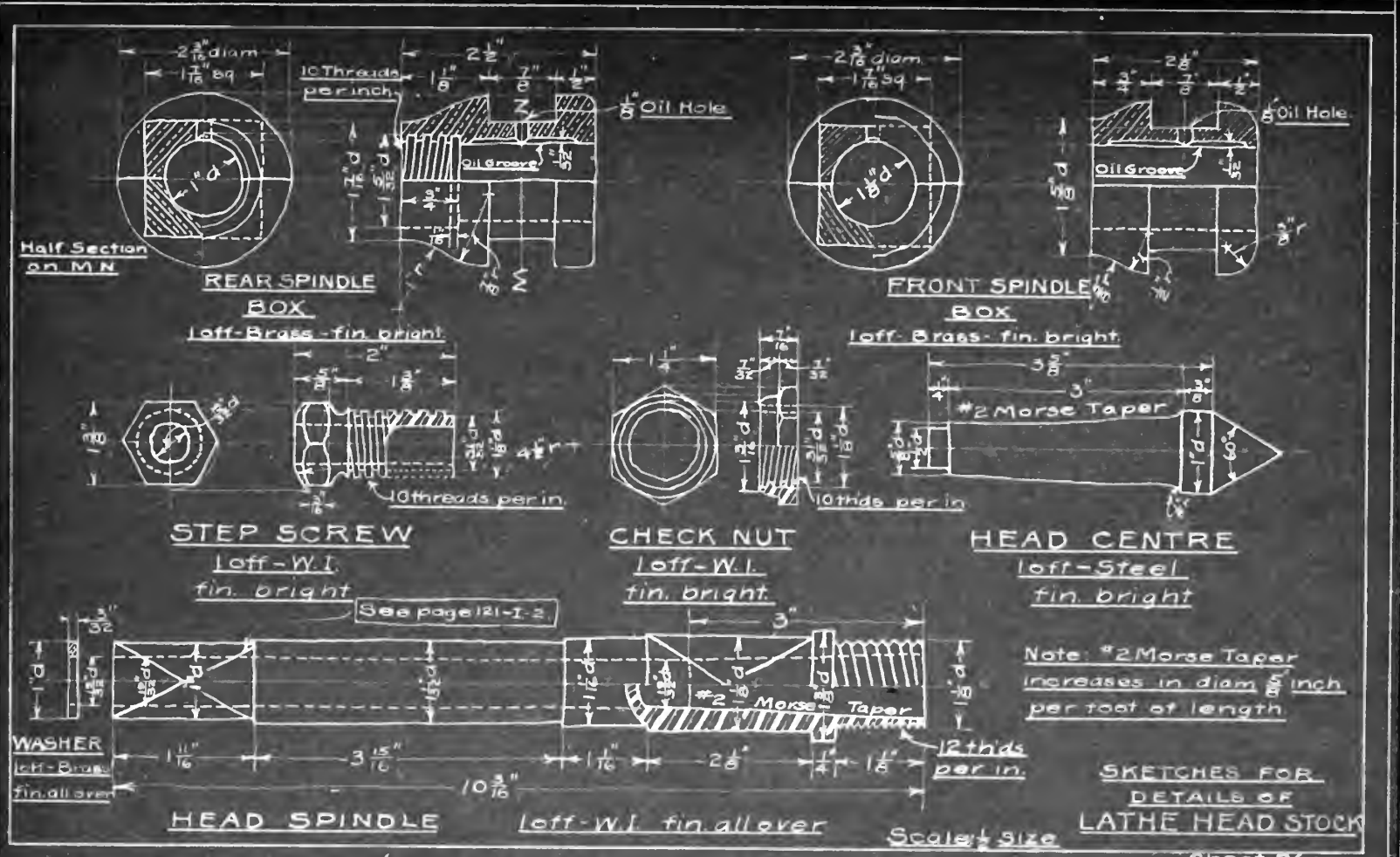
ARRANGEMENT OF STANDARD TITLE

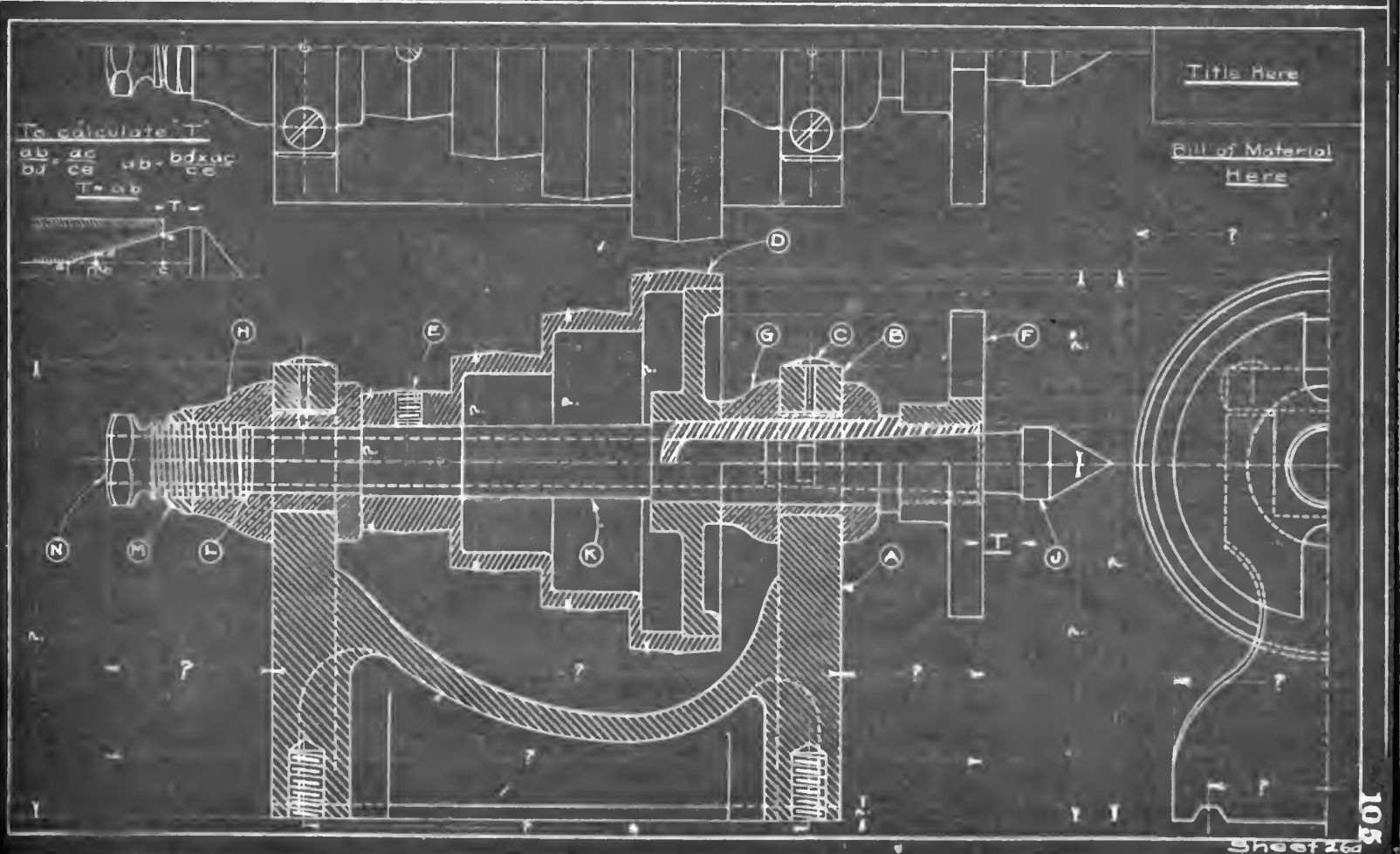
Frame - 6"x3"

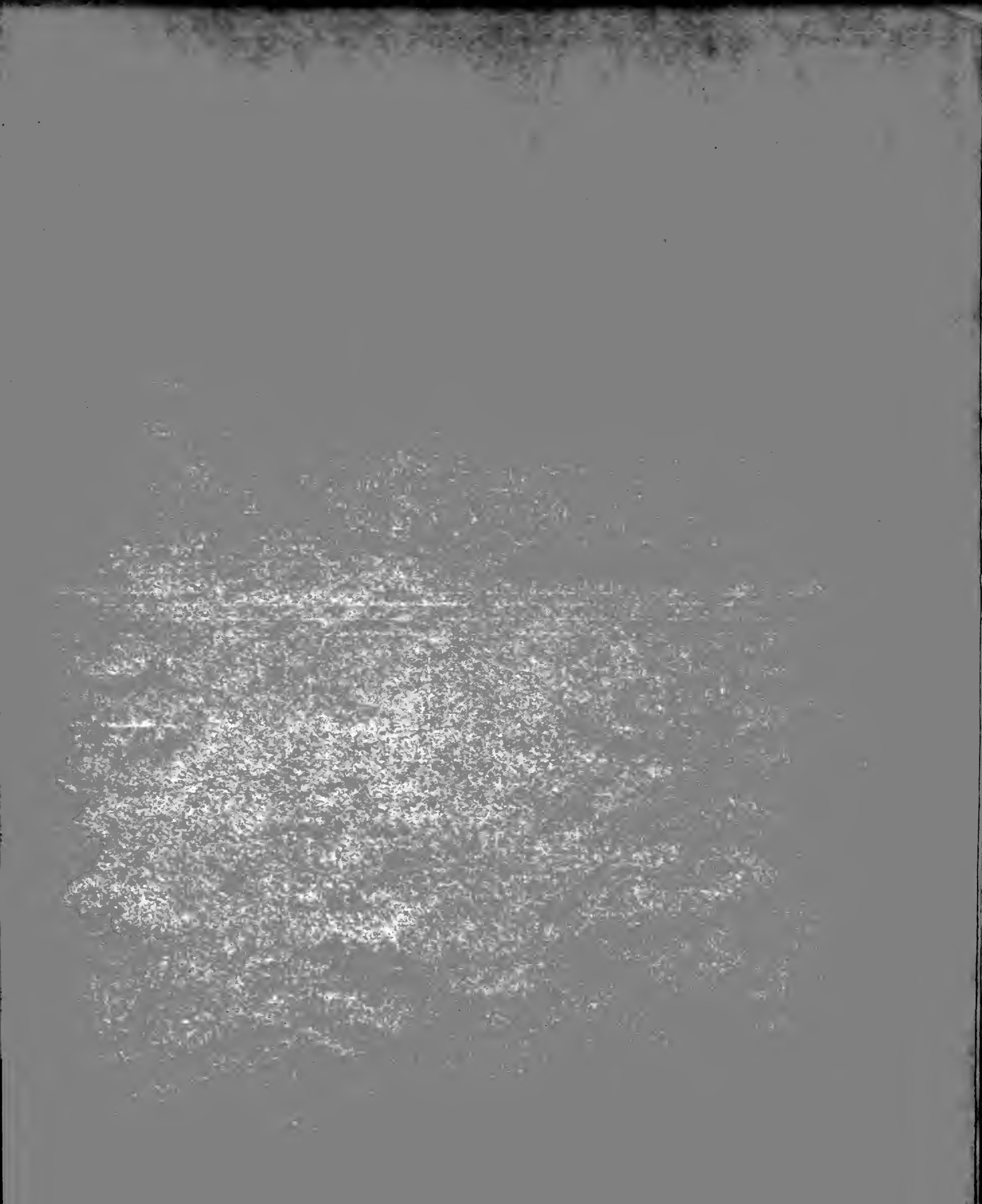


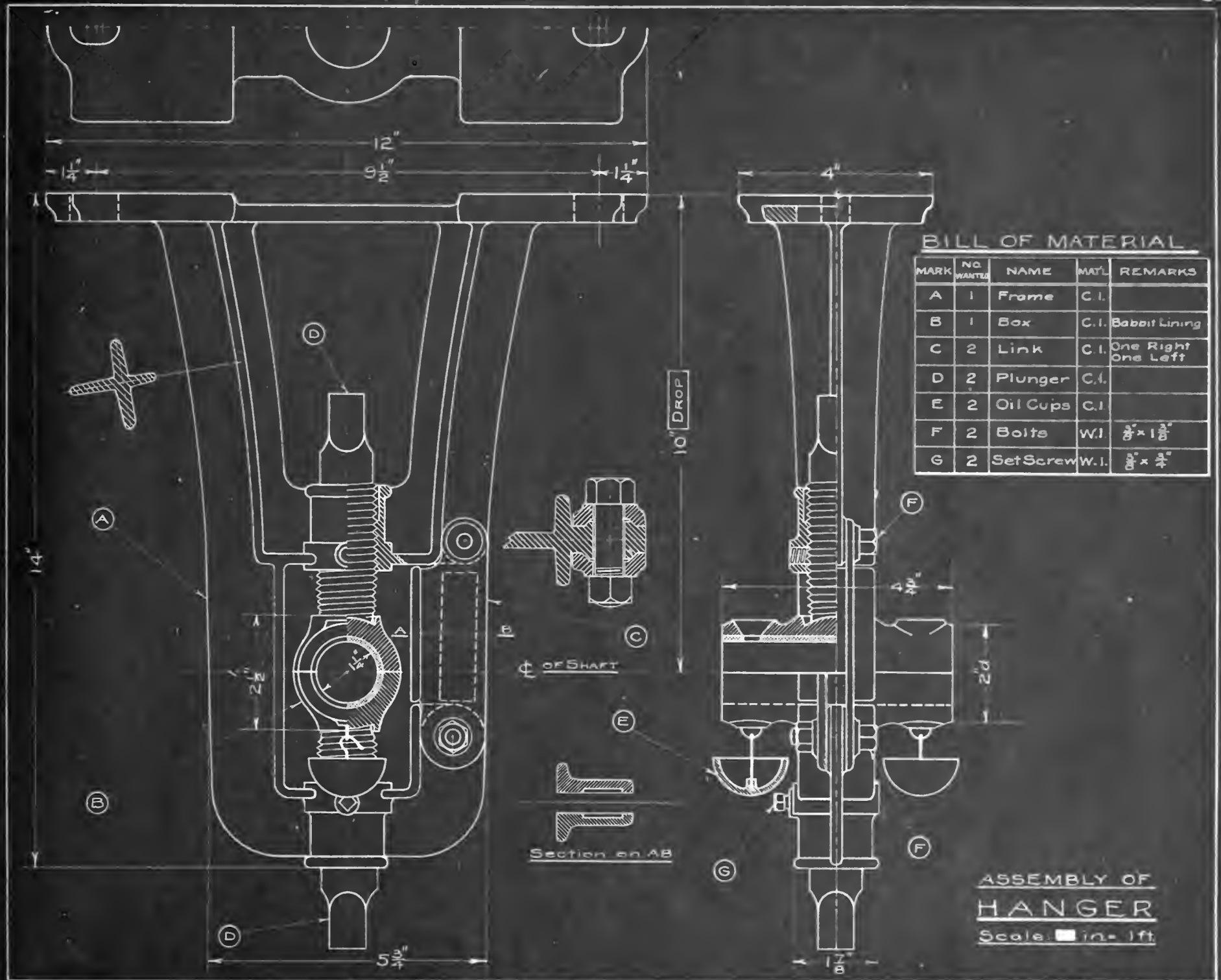

CAP
2 off - C.I.
Fin. all over
℄ of Spindle
Tap for ½" Bolt
Note = 1 21/32"
1/8" Oil Hole
Drill and Ream for 3/8" Mach. Screw
Tap for 3/8" Mach. Screw
Section on RS
MACH. SCREW
4 off - W.I.
"V"
ENLARGED DETAIL OF "V"
HEAD
1 off - C.I.
Complete
SKETCHES FOR DETAILS OF LATHE HEAD STOCK
Scale: ½ Size
Sheet 26a


SET SCREW
1 off Steel
Driving Fit
CONE PULLEY
1 off - C.I.
fin. all over
FACE PLATE
1 off - C.I.
fin all over
12 threads per in
SKETCHES FOR DETAILS OF LATHE HEAD STOCK
Scale: ½ Size
103
Sheet 26b


Half Section on M N
REAR SPINDLE BOX
1 off - Brass - fin. bright
FRONT SPINDLE BOX
1 off - Brass - fin. bright
10 Threads per inch
Oil Hole
Oil Groove
STEP SCREW
1 off - W.I. fin. bright
See page 121-I-2.
CHECK NUT
1 off - W.I. fin. bright
HEAD CENTRE
1 off - Steel fin. bright
#2 Morse Taper
10 threads per in.
12 thds per in.
WASHER
1 off - Brass fin. all over
HEAD SPINDLE
1 off - W.I. fin. all over
Note: #2 Morse Taper increases in diam .599 inch per foot of length
SKETCHES FOR DETAILS OF LATHE HEAD STOCK
Scale ½ size
Sheet 26c


Title Here
Bill of Material Here
To calculate "T"
T = ab
A
B
C
D
E
F
G
H
J
K
L
M
N
T
105
Sheet 26d

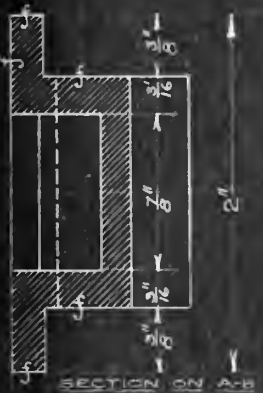




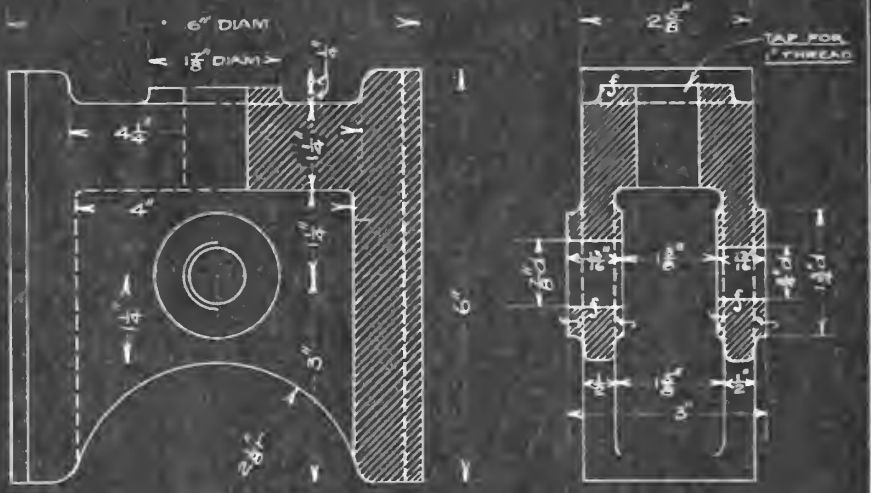
BILL OF MATERIAL

MARK	NO WANTED	NAME	MAT'L	REMARKS
A	1	Frame	C.I.	
B	1	Box	C.I.	Babbit Lining
C	2	Link	C.I.	One Right One Left
D	2	Plunger	C.I.	
E	2	Oil Cups	C.I.	
F	2	Bolts	W.I.	⅜" × 1⅜"
G	2	Set Screw	W.I.	⅜" × ¾"

ASSEMBLY OF
HANGER
Scale ■ in. 1 ft



SLIDE VALVE

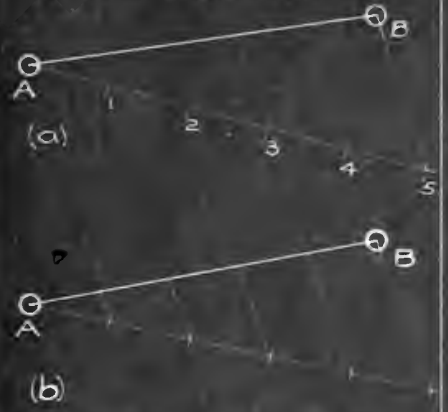


CROSS HEAD

EXERCISES


a b c d e f g h i j k l m
n o p q r s t u v w x y z
A B C D E F G H I J K L M
N O P Q R S T U V W X Y Z
1 2 3 4 5 6 7 8 9 0 &
1/4 5/8 7/16 9/32
34' - 7 1/8"
18.09

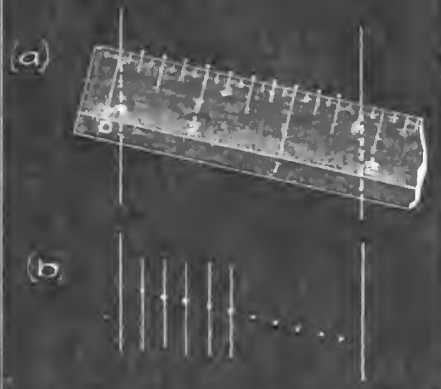
1 To divide a line AB into (say) 5 parts



(a) 5 spaces (any size) on A5 (any line). Join 5B.

(b) Lines parallel to 5B give required divisions.

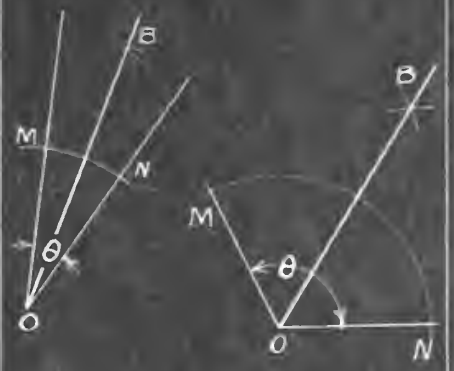
2 To divide a space into (say 11 parts) for parallel lines.



(a) Point off 11 units any size. Use scale as shown.

(b) Draw parallel lines.

3 To bisect an angle θ

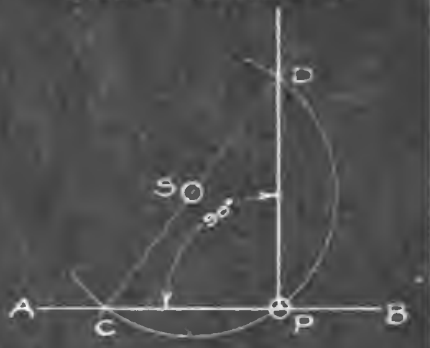


(1) arc MN - any radius

(2) arcs at B - centers at M and N

(3) OB = bisector.

4 To erect a perpendicular to AB at P



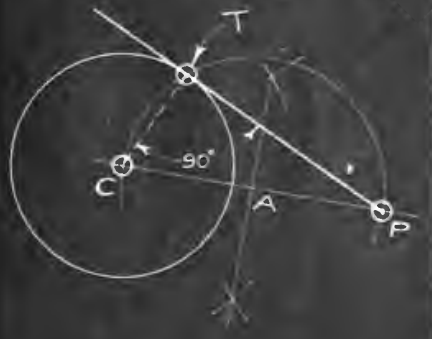
(1) S = any point

(2) Circle thro P. S = center.

(3) CD thro S

(4) PD = required perpendic.

5 To draw a tangent to a circle from a point P.

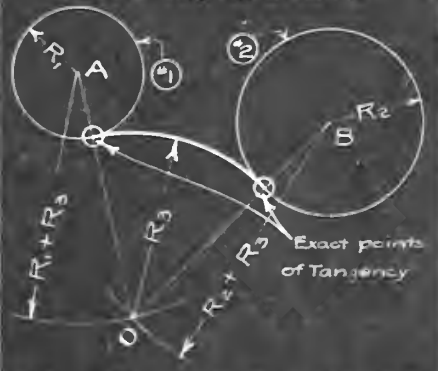


(1) Semi-circle on PC - A = center.

(2) PT = required tangent.

6 To draw an arc tangent to 2 given circles, #1 and #2.

Given R_1, R_2 and R_3



(1) Arcs from A + B meet at O

2 O = center of required tangent arc.

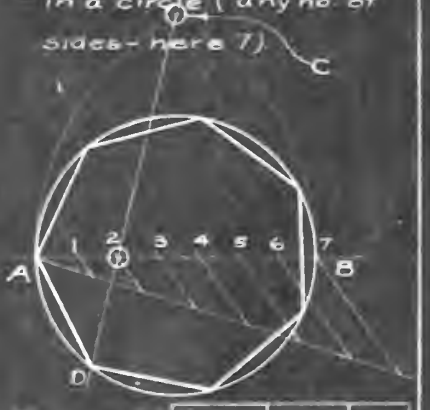
7 To pass an arc thro 3 points, A, B and C.

(1) Lines AB and BC

(2) ⊥'s at middle pts meet at O

(3) O = center of required circle.

8 To inscribe a polygon in a circle (any no. of sides - here 7)



for	5 sides -	7 sides -	ETC.
(1) Divide AB into	5 parts	into 7 ...	ETC.

(2) Arcs AC + BC (A + B = centers)

(3) CD always thro second point.

(4) AD = required side.

SHADING

(Usually in Inking only)

1. To give the effect of RELIEF to a drawing the Convention of Shading is often adopted.
2. The light is assumed to come in the direction of arrows - Fig 1
3. All Bounding Lines which light does not strike directly are shaded.
   The shaded lines are simply inked somewhat heavier than the unshaded to give the effect of casting a shadow.
4. In general, Dotted Lines and Lines representing the intersection of two planes, both of which are visible, are not shaded.
5. SHADING CIRCULAR ARC (Fig 2).
   Draw circle - centre A
   With SAME RADIUS and Centre at B (AB - abt 1/32") draw second arc from C to D. Similarly for small circle which represents a hole.

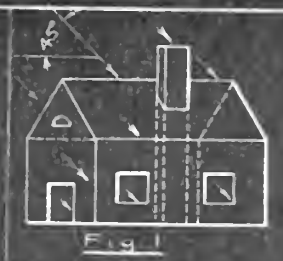
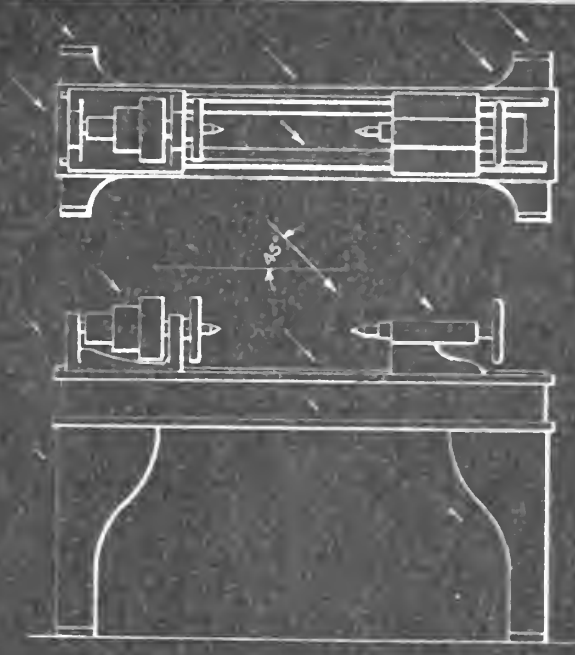


Fig 1

Note: All views of an object are shaded in same manner as above.

Fig 2

I



LATHE

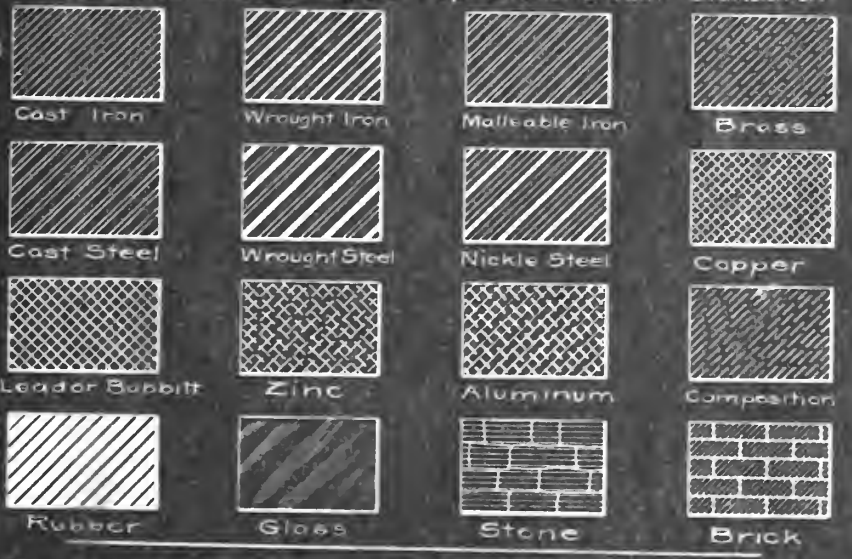
(Illustration of Shading)

II

SOME CONVENTIONS FOR CROSS SECTIONS

Practice differs - these represent a fair standard.

(1)



(2) Usual angle for Cross hatching = 45°

(3) Two or more separate pieces in contact are hatching in different directions.

III

(1) TYPES OF LINES

(a) Full (visible)
(b) Dotted (invisible)
(c) or (d) Centre Lines

Dimension and Extension Lines — or

(2) NUMBER OF PIECES WANTED

(a) "Two"
(b) "Two of this"
(c) "Make Two"
(d) "2 Off" or "Two Off"
(e) "2 Pieces" or "Two Pieces"
(f) "2 Wanted" or "Two Wanted"

(3) WITNESS MARKS

(a) 12 Thrd per in.
(b) A
(c) 1/8" drilled
(d) 5/8" Tap

(4) FINISH MARKS

(a) f
(b) f — For Part of Surface
(c)
(d) faced

IV

SOME CONVENTIONS

IN GENERAL

(1) First dimension that view which shows details most clearly

(2) Avoid repeating dimensions on a second view.

(3) Dimension where possible to centre lines and finished surfaces

(4) Place dimensions outside of drawing if confusion would result from placing them inside.

(5) Dimension distances only in those views where they appear in their true length

SYMBOLS

(1) 9" = 9 inches 13" = 13 inches etc.

(2) 4' or 4'-0" = 4 feet 5'-6" = 5 feet-6 inches

(3) Under 2 ft use inches; above 2 ft use feet and inches.

(4) 3" diam. or 3" d. = 3 inches diameter.

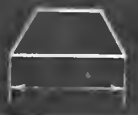
(5) 3" rad. or 3" r = 3 inches radius.

CONVENTIONS AND ILLUSTRATIONS

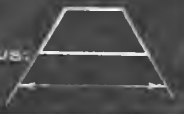
(1) Fractions thus: $\frac{3}{4}$" not thus: 3/4"

(2) Arrow Points thus: ← not thus: ← nor ←

(3) Extension Lines thus:

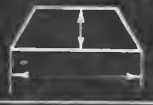


not thus:



(4) Arrow Points always to touch lines dimensioned

thus:



not thus:

(5) Arrow Points always opposite

thus: ←→ or →← not thus: ←←

(6) Horizontal Dimensions thus: ←2 5/16"→

(7) Vertical Dimensions

thus:

not thus

nor

ie: (Vertical Dimensions to read from RIGHT.)

CONVENTIONS AND ILLUSTRATIONS - cont

(8) Slanting Dimensions thus:

(9) Small Dimensions thus: $\frac{3}{32}$" or thus $\frac{1}{16}$"

(10) Avoid using LINES OF DRAWING or CENTRE LINES as Dimension Lines.

Correct thus:

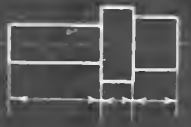
not thus

(11) Diameters thus:

(12) Radii thus: (only one arrow)

(13) Carry Dimensions where possible along one line

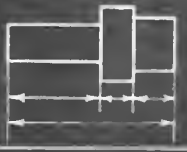
thus:



not thus:

(14) Give Dimension "Over All" as well as subdimensions

thus:



(15) Decimal Dimensions thus: 4".06 not 4.06"

CONCERNING DIMENSIONS

U.S. STANDARD FOR 'V' THREADS

Size of Bolt	Threads per inch	Diam. at root of thread	Diam. of Tap Drill
1/8	16	.295	9/64
7/16	14	.344	23/64
1/2	13	.400	13/32
9/16	12	.454	15/32
5/8	11	.507	17/32
3/4	10	.620	5/8
7/8	9	.731	3/4
1	8	.837	27/32
1 1/8	7	.940	31/32
1 1/4	7	1.065	1 3/32
1 3/8	6	1.169	1 3/16
1 1/2	6	1.284	1 9/32
1 5/8	5 1/2	1.389	1 13/32
1 3/4	5	1.491	1 1/2
1 7/8	5	1.616	1 5/8
2	4 1/2	1.712	1 3/4
2 1/4	4 1/2	1.962	1 31/32
2 1/2	4	2.176	2 3/16
2 3/4	4	2.426	2 7/16

I.

II.

STANDARD PIPE THREADS

Taper of threads = 1/4 on diam. per in.

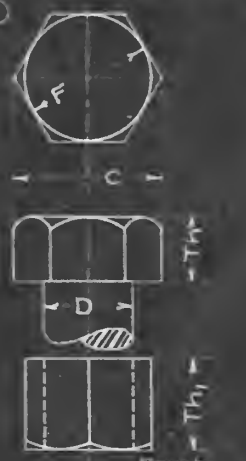
Nominal Size of Pipe	Outside Diam.	Thickness of Metal.	Threads per inch.
1/8"	0.405	.068	27
1/4	0.540	.088	18
3/8	0.675	.091	18
1/2	0.840	.109	14
3/4	1.050	.113	14
1	1.315	.134	11 1/2
1 1/4	1.660	.140	11 1/2
1 1/2	1.900	.145	11 1/2
2	2.375	.154	11 1/2

III

U.S. STANDARD BOLTS AND NUTS

HEXAGONAL

Chamfered



Rough
F = 1 1/2 D + 1/8"
C = F × 1.15
Th = 1/2 F
Th1 = D

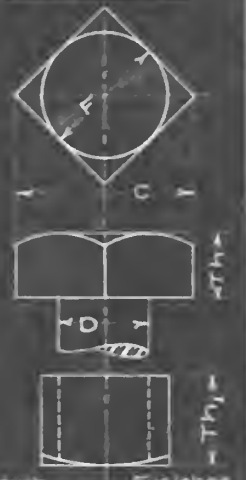
Rounded

Finished
F = 1 1/2 D + 1/16"
C = F × 1.15
Th = 1/2 F
Th1 = D - 1/16"

IV.

SQUARE

Chamfered



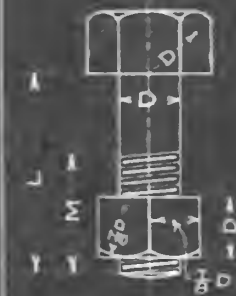
Rough
F = 1 1/2 D + 1/8"
C = F × 1.41
Th = 1/2 F
Th1 = D

Finished
F = 1 1/2 D + 1/16"
C = F × 1.41
Th = 1/2 F
Th1 = D - 1/16"

V.

CONVENTIONAL METHOD

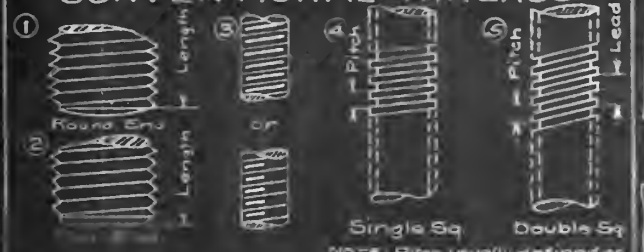
OFTEN USED IN DRAWING SMALL HEXAGONAL BOLTS



Necessary Dimensions = D. L. M.

VI.

CONVENTIONAL THREADS



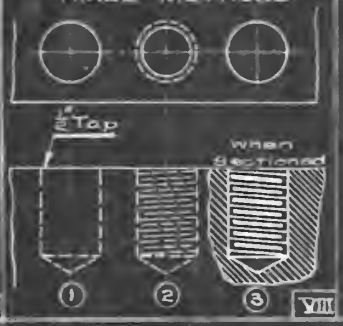
NOTE: Pitch usually defined as 8 threads per inch, 10 thds. p. in., etc.

For Large 'V' Threads — For Small 'V' Threads

VII.

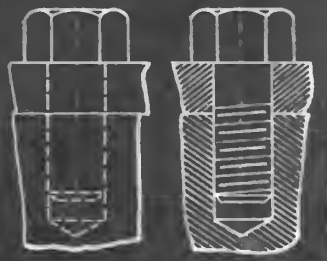
TAPPED HOLES

THREE METHODS



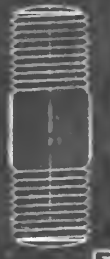
VIII.

BOLTS IN PLACE



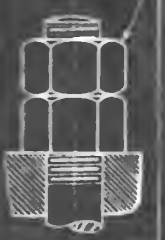
IX.

STUD BOLT



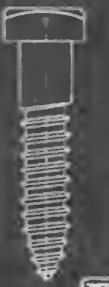
X.

CHECK NUT



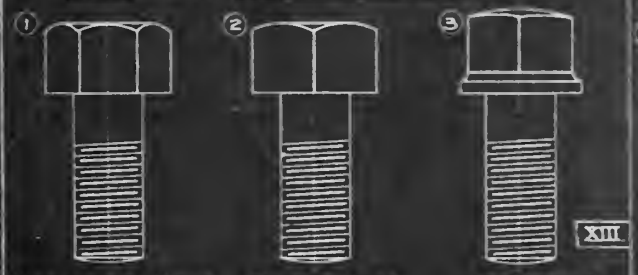
XI.

LAG SCREW



XII.

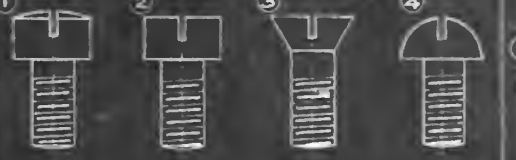
CAP OR TAP BOLTS



Hexagonal Head — Square Head — Collared

XIII.

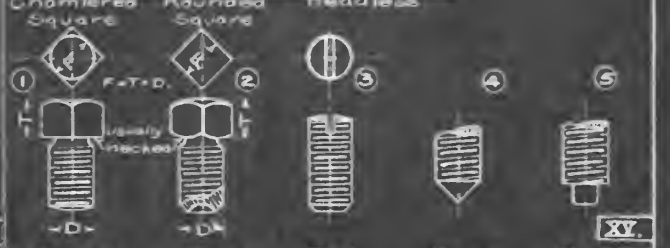
CAP OR MACHINE SCREWS



Fillister Head — Round or Cheese Head — Flat or Countersunk — Button Head

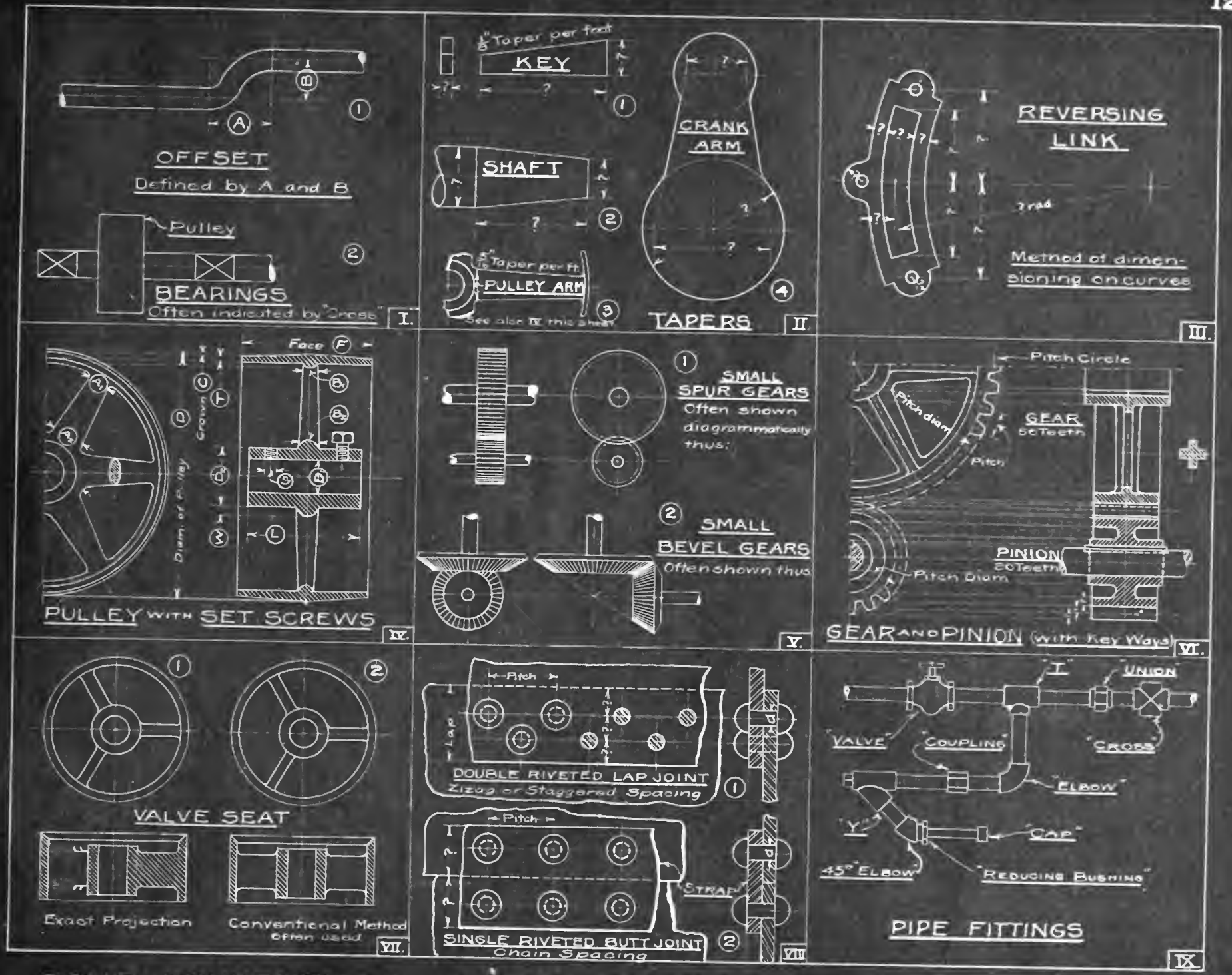
XIV.

SET SCREWS



XV.

References — Reid, Ellerman, Mass. Inst. Tech. — Bartlett, Mech. Draw., pp. 73-75 — Anthony, Mach. Drawing, Chap. I



SOME CONVENTIONS IN DIMENSIONING AND DRAWING

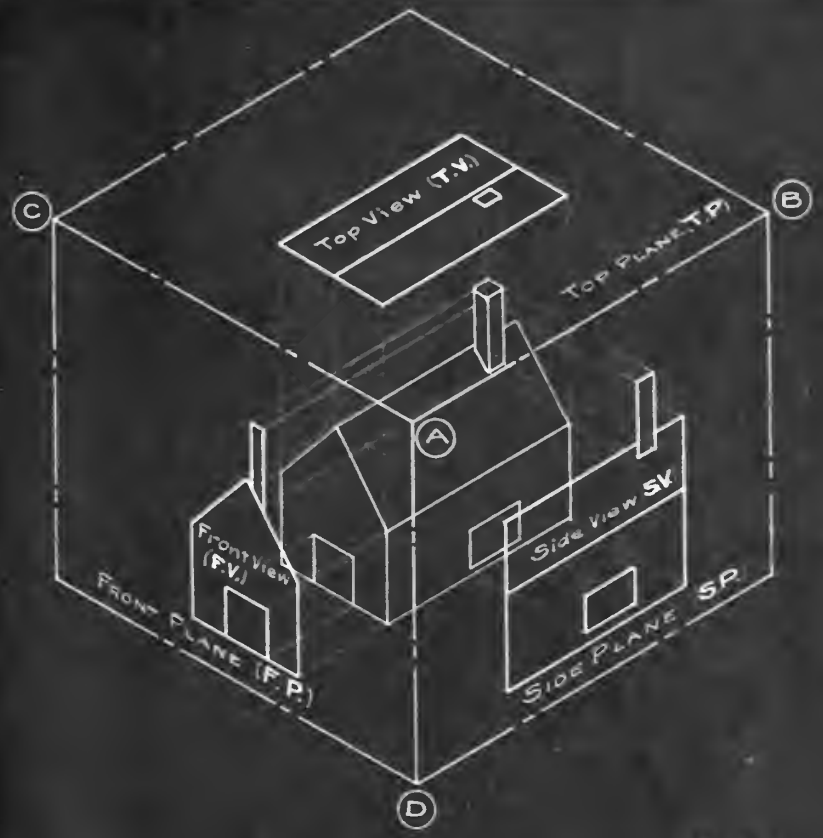


Fig. 1

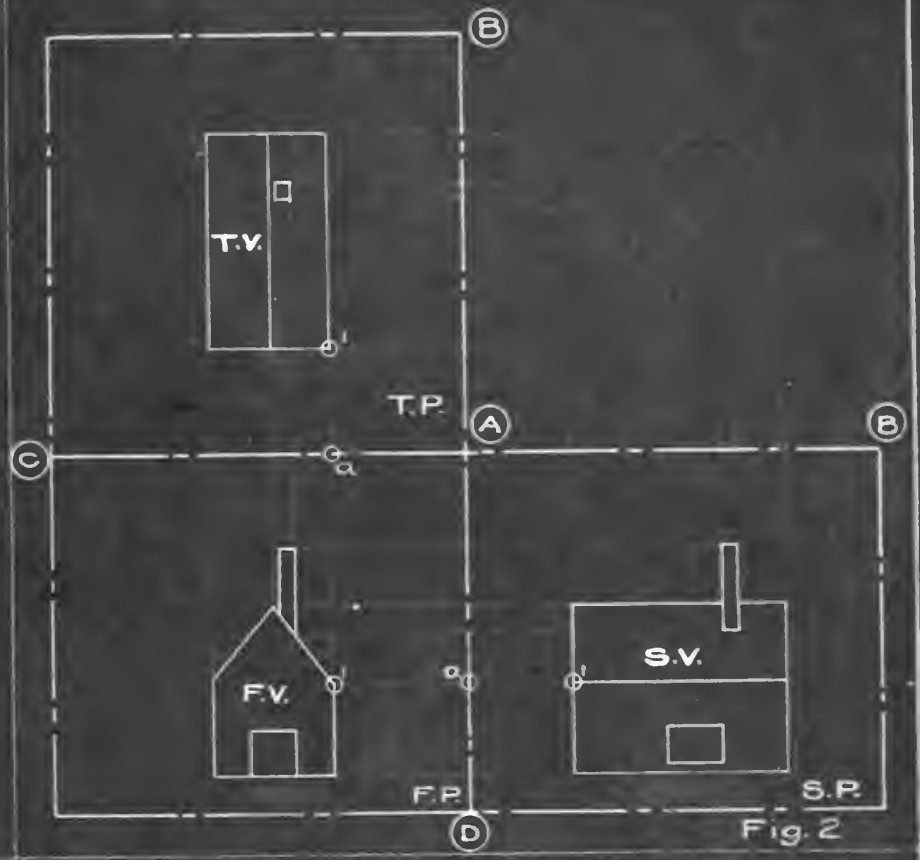


Fig. 2

1. Consider object surrounded by THREE PLANES, **F.P.**, **S.P.** and **T.P.** as shown (Fig. 1). These planes are called "PLANES OF PROJECTION"

2. Let rays perpendicular to each plane respectively, pass from every point of object to these planes.

3. The intersection of these rays and their respective planes will trace Three Views, **F.V.**, **S.V.**, + **T.V.** as shown (Fig. 1).

4. These views are called the **PROJECTIONS*** of the object

5. Consider the PLANES OF PROJECTION to be separated along **AB**. Turn **T.P.** on **AC** and **S.P.** on **AD** and spread all three planes out flat. The resulting location of the views will be as in Fig. 2.

6. Note that a. **T.V.** is above **F.V.**, and **S.V.** at side of **F.V.**§
   b. Point 1 in **T.V.** is VERTICALLY over point 1 in **F.V.**
   c. Point 1 is on same HORIZONTAL LINE in **S.V.** and **F.V.**
   d. Distance **a,1** in **S.V.** = distance **a,1** in **T.V.**
   These 4 relations are true for all corresponding pts in the 3 Views

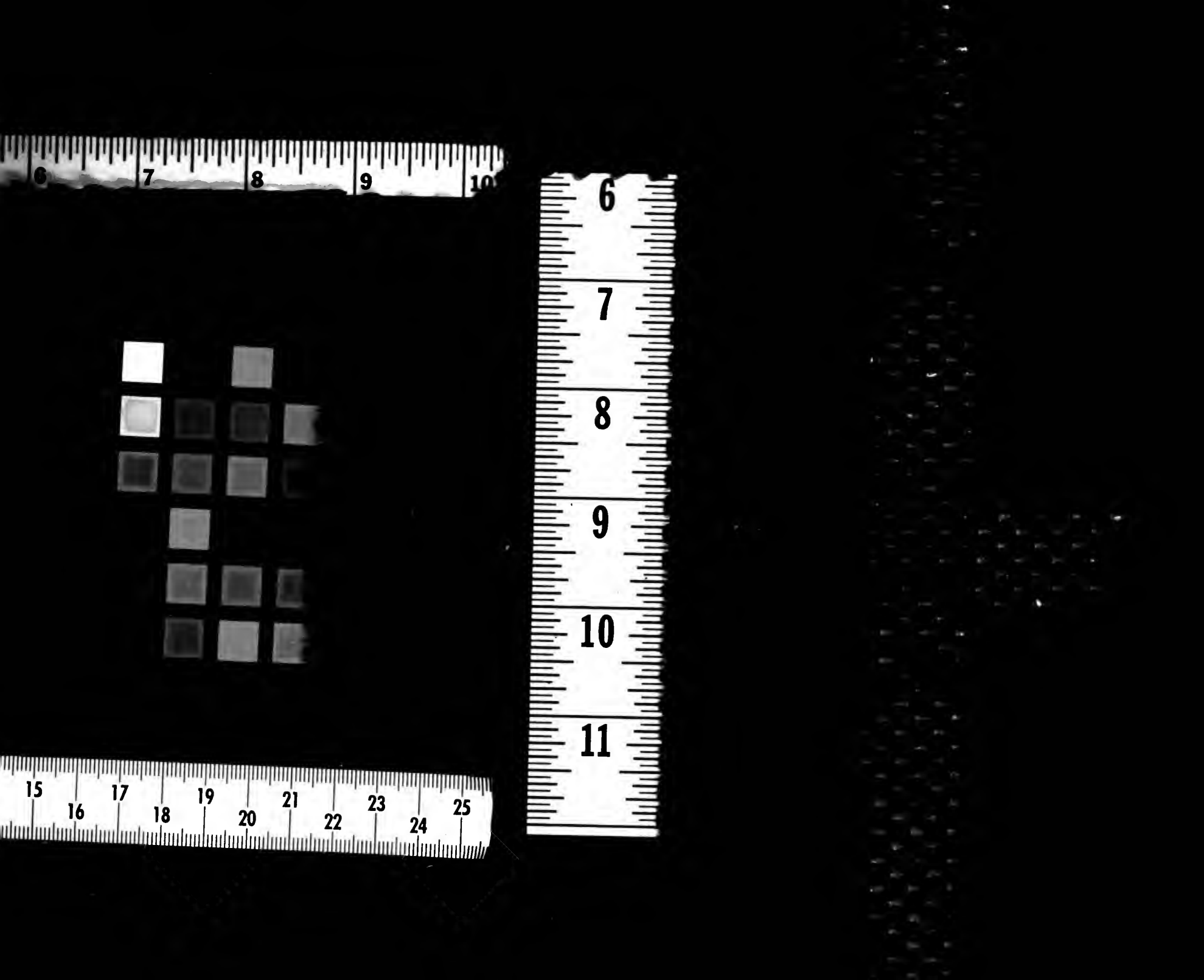
7. The above principles apply to the representation of all objects by the method of ORTHOGRAPHIC PROJECTION

* Note (a) More accurately, the "ORTHOGRAPHIC PROJECTIONS" because the rays make RIGHT ANGLES with their respective planes – ὀρθός = Right + γράφειν = to Draw.
(b) By additional planes a BOTTOM VIEW, a LEFT SIDE VIEW and a REAR VIEW can be obtained.

§ NOTE: F.V. often called FRONT ELEVATION.
S.V. " " SIDE ELEVATION.
T.V. " " PLAN.

ORTHOGRAPHIC PROJECTION

J22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